BUREAU OF SHIPS
MANUAL

CHAPTER 94
SECTION I

SUBMARINE SAFETY

Respiration and Rescue Devices

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CHAPTER 94

SECTION I

Title:

SUBMARINE SAFETY

Respiration and Rescue Devices

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This chapter is a revision of Bureau of Ships Manual, Chapter 94, "Submarine Safety, Respiration and Rescue Devices," dated 19 March 1945.

This revised chapter becomes effective upon receipt, and shall be inserted in its proper place in the Manual binder.

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Chapter 94

SUBMARINE SAFETY; RESPIRATION AND RESCUE DEVICES

SECTION I

CONTENTS

Part 1. The "Lung"

94–1. PURPOSE AND DESCRIPTION

(1) The Navy submarine escape "Lung" is designed to provide individual crew members of submarines with a reasonably safe means of escape from disabled sunken vessels.

(2) The constituent parts of the "Lung" and their functions are as follows. (See figs. 94–1 to 94–5 inclusive.)

(*a*) *Nose Clip.*—Part (1) is a nose clip for sealing the nostrils. While development and training work have indicated that some trained users of the Lung can, by constriction of their nostrils, dispense with the use of the nose clip, this procedure is not advocated by the Bureau. The nose clip should be worn whenever the Lung is used for making an ascent. The rubber pads of the clip have been made slightly larger and the spring tension stronger than in clips used in the old-style breathing apparatus. This has been found necessary in order to conform with the requirements of varying nasal contours and to meet the more adverse conditions of sealing the nostrils when under pressure.

(*b*) *Cut-off Valve.*—Part (2) is a cut-off valve for cutting off or permitting the inhalations and exhalations to pass to and from the breathing bag. Under normal storage conditions, this valve should always be closed to keep air and moisture from the soda lime in the canister (6). When in use, the valve is open. After ascent to the surface, the closing of the valve in conjunction with the closing of the relief valve (16) prevents deflation of the bag, which can then be depended upon to support the wearer on the surface.

(*c*) *Rubber mouthpiece.*—Part (3) is a rubber mouthpiece containing rubber lugs that are gripped between the wearer's teeth and two vertical rubber fins which form a groove enclosing the upper and lower lips of the wearer. The outer fin, in addition to affording muscular support to the lip muscles, presses against the upper lip under the nostril, preventing sneezing. A cored center in the mouthpiece acts as a conduit for inhalation and exhalation of air. This rubber mouthpiece is connected to a metal housing (4).

(*d*) *Metal housing.*—Part (4) is a metal housing or metal mouthpiece containing metal partitions and mica disc flapper valves which control the directional flow of the inhalation and exhalation air. It also contains the cut-off valve (2) referred to above. The lower end of the metal mouthpiece is fitted with a threaded winged nut (5) to take the canister nipple (18) on the breathing bag (10).

(*e*) *Air chuck.*—Part (8) is a Schrader air chuck such as is used on the air hose of automobile service stations for inflating automobile tires. These chucks are fitted to standard oxygen hoses (13) with which the manifolds of the oxygen flasks on submarines have been provided.

(*f*) *Oxygen-inlet valve.*—Part (9) is the oxygen-inlet valve by means of which oxygen is introduced into the bag. This valve is the Schrader standard automobile tire valve with the exception of a special spring that provides for proper seating of the valve under about one-half p. s. i. instead of the 35 p. s. i. usually applied to automobile tire tubes.

(*g*) *Breathing bag.*—Part (10) is a breathing bag of the bellows type, the internal volume of which when inflated is approximately equal to the air ca-

FIGURE 94–1.

1. Nose clip
2. Shut-off valve
3. Rubber mouthpiece
4. Metal mouthpiece (housing)
5. Winged connecting nut
6. Canister (inside bag)
7. Combination filler and respirator cap
8. Air chuck
9. Oxygen inlet valve
10. Breathing bag
11. Chains for trouser clamps
12. Trouser clamps
13. Oxygen hose
14. Belt strap
15. Shoulder strap
16. Relief valve (flutter)
17. Clamp for belt strap

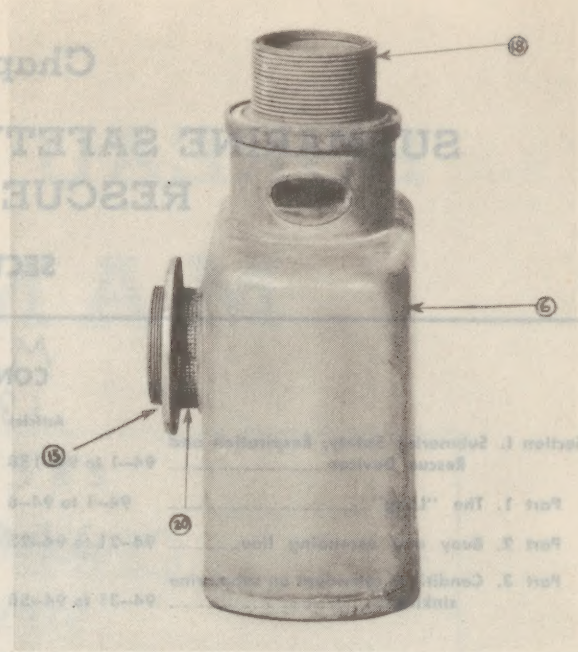

FIGURE 94–3.—Side view of canister.

6. Body
18. Threaded connection for winged nut
19. Flange
20. Screened ports

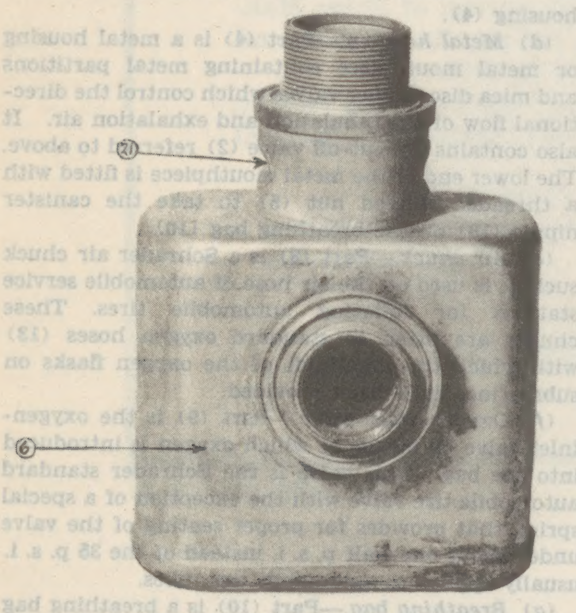

FIGURE 94–2.—Front view of canister—without filling plug.

6. Body
21. By-pass for exhalations

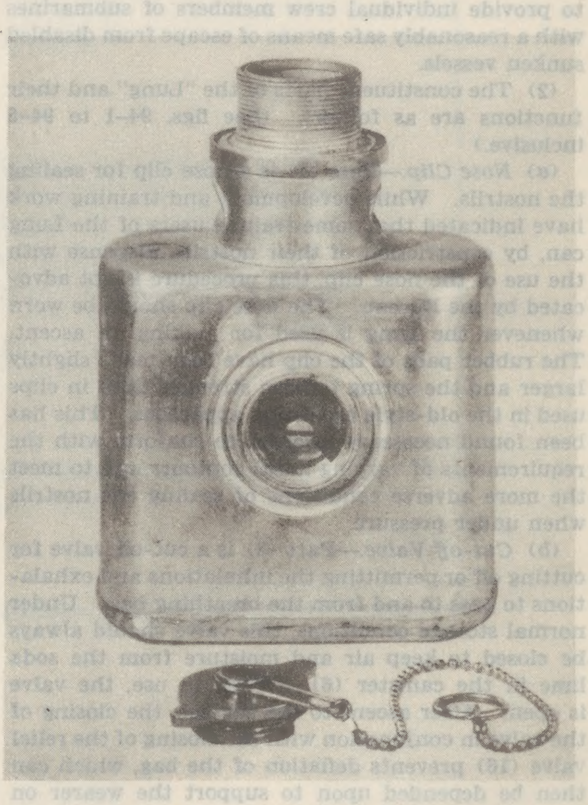

FIGURE 94–4.

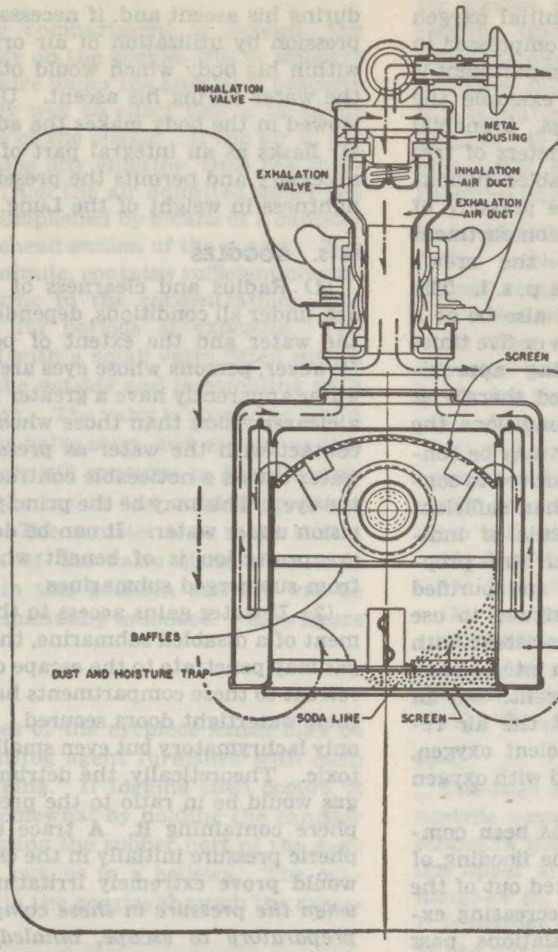

FIGURE 94–5.—Cross section of "Lung" and canister of same showing directional flow of inhalations and exhalations.

pacity of the lungs, bronchial tracts, etc., of the average individual. The bag is made of the best grade of stockinette covered rubber, the compound of which contains special antioxidants that contribute to the longevity of the rubber. The stockinette covering has also been placed over the rubber on the inside of the bag to prevent the front and back of the bag sticking together under stowage conditions.

(*h*) *Relief valve.*—Part (16) is a relief or internal pressure equalizing valve. It is of the rubber flutter valve type. It is connected to the bag by means of a tubular metal connection. The valve is carefully adjusted on the metal connection so that it extends a certain definite distance below the bottom of the bag. This distance should not be changed. The difference between the pressure of the water surrounding the valve outlet and that surrounding the bag, plus the pressure of the air exhaled during ascent is sufficient to maintain an air pressure within the bag of about one-eighth to one-fourth pound in excess of the surrounding water pressure irrespective of the depth.

(*i*) *Clamps.*—Part 12 shows the small metal clamps by means of which the Lung is clamped to the trousers to prevent its floating upward on the wearer's body when submerged.

(*j*) *Clamp chains.*—Part 11 are small metal chains by means of which the metal clamps (part 12) are permanently attached to the breathing bag.

(*k*) *Belt strap.*—Part 14 is a belt strap made of one-half inch wide webbing. One end of the strap is fitted with a clamp (17) similar in design to those shown as part (12) but larger. The belt strap is secured around the wearer's waist by means of this clamp.

(*l*) *Shoulder strap.*—Part 15 is a shoulder strap of one-half inch wide webbing. The straps are fitted with sliding buckles for adjustment purposes.

(*m*) *Oxygen hose.*—Part (13) shows the oxygen hose, four short lengths of which are normally connected to the manifolds of the oxygen flasks stowed in escape compartments. The outer end of this hose, as mentioned above, is fitted with a Schrader air chuck (8) which is momentarily connected to the oxygen inlet valve (9) on the breathing bag (10) when it is desired to inflate the latter.

94–2. PRINCIPLE OF OPERATION

The principle of operation of the "Lung" is as follows:

(1) The appliance is designed to furnish a respirable supply of air during ascent and decompression

by utilizing, in conjunction with an initial oxygen inflation of the bag, the air which is compressed in the wearer's body when a submarine compartment is flooded preparatory to escape. For example the normal average capacity of the lungs, bronchial tracts, etc., is about 3,500 cubic centimeters of free air at atmospheric pressure. In a disabled submarine, sunken, say at 165 feet, the gage pressure of the air "bubble" formed by flooding a compartment or an escape lock preparatory to the crew's emergence would be approximately 73½ p. s. i. The air within the occupant's lungs would also be at a pressure of 73½ pounds per square inch or five times atmospheric pressure, the volume being approximately five times the volume contained therein at atmospheric pressure. Under such conditions the lungs and air tracts of the human body may be considered as a reservoir which tests have proved to contain an amount of air which is more than sufficient to fill ordinary respiratory requirements of individuals during their ascent provided such air is properly regulated, enriched with oxygen, and purified before reinhalation. The Lung is designed to use as large a portion of this air as is consistent with the maintenance of equilibrium between internal and external pressures during a man's ascent. As an additional reserve and to insure that the air rebreathed by the wearer contains sufficient oxygen, the breathing bag of the Lung is inflated with oxygen prior to the man's emergence.

(2) During ascent the air which has been compressed in the wearer's body during the flooding of the compartment or escape lock is forced out of the lungs by exhalation in ratio to the decreasing external water pressures. These exhalations pass through mouthpiece (3) of the Lung into the metal housing (4) in which mica disc valves direct them to exhalation air duct (Fig. 94–5) and thence into breathing bag (10) mixing with the air therein which has been previously enriched by the initial oxygen inflation. Inhalations draw this air up through the soda lime container where it is purified (CO_2 removed) before passing into inhalation air duct (Fig. 94–5) in the metal mouthpiece. From the latter the air flows through the metal housing to the rubber mouthpiece (3) and thence to the wearer's mouth. The inhaled air, when flowing into the metal housing, is prevented from flowing into the exhalation air duct by mica disc flapper valves in the housing. Air in excess of that required to keep the breathing bag inflated to about one-fourth p.s.i. over the surrounding water pressure automatically escapes through the relief valve (16) (Fig. 94–1). This function of the relief valve combined with the position of the Lung on the body and the relative position of its constituent parts maintains equilibrium at all times between internal pressures and that of the surrounding water and maintains the bag at constant displacement or buoyancy irrespective of the depth of water from which ascent is made. These characteristics permit the wearer of the "Lung" to breathe during his ascent and, if necessary, stop for decompression by utilization of air originally compressed within his body which would otherwise escape into the water during his ascent. Utilization of the air stowed in the body makes the addition of oxygen or air flasks as an integral part of the apparatus unnecessary and permits the present compactness and lightness in weight of the Lung.

94–3. GOGGLES

(1) Radius and clearness of vision under water are, under all conditions, dependent on the clarity of the water and the extent of penetration of light. However, persons whose eyes are protected from the water apparently have a greater radius of vision and a clearer vision than those whose eyes are in direct contact with the water as pressure exerted by the water causes a noticeable contraction of the pupil of the eye. This may be the principal cause of reduced vision under water. It can be definitely stated that eye protection is of benefit when making ascents from submerged submarines.

(2) If water gains access to the battery compartment of a disabled submarine, the resultant chlorine gas may penetrate to the escape compartment before retreat to these compartments has been effected and their watertight doors secured. Chlorine gas is not only lachrymatory but even small concentrations are toxic. Theoretically, the detrimental effects of this gas would be in ratio to the pressure of the atmosphere containing it. A trace of it under atmospheric pressure initially in the escape compartments would prove extremely irritating to the eyes, and *when the pressure in these compartments is raised, preparatory to escape, inhaled chlorine gas may cause death.* Therefore, not only eye protection but respiratory protection of the personnel in the escape compartments is essential under such conditions.

To provide for this need goggles are issued as a part of the "Lung" equipment. They are designed to be:

(a) Watertight at all depths.

(b) Gastight at atmospheric pressure and at high pressures.

(c) So that the air pressure under the goggles can be equalized with the pressure of the outside medium.

(d) So that when lachrymatory gases are present in the surrounding medium, equalization of air pressure under the goggle can be effected without contamination of the air under the goggle.

As designed they cover the eyes, the lower part of the forehead, cheeks, and bridge of the nose of the wearer. (See figure 94–6.) They are made of rubber molded in such a manner as to afford a gas- and water-tight seal when worn by personnel of varying facial contours. The eye pieces are shaped to give the maximum downward and upward vision. Adjustment of the goggles to the face is made by means of an elastic head strap.

94-4.

When an escape compartment is flooded, the resultant air pressure on the goggles will be unbearable unless air pressure under the goggles is properly equalized. The only way to effect this is to admit air to the under side of the goggle. If the air in the compartment contains any chlorine, then the chlorine must be freed from the air admitted under the goggle. This is accomplished by means of a canister mounted on the forehead section of the goggle. The canister, although minute, contains sufficient chemical to absorb chlorine in the concentrations that might be expected for periods of exposure. The canister is provided with a small valve fitted with a stem extending to the outside and terminating with a knurled edge button. The valve is opened to admit air by depressing the valve stem, and as long as this valve is held open, air will continue to flow through the canister until the inside and outside pressures are in equilibrium. The canister is so made that a partial rotary turn of the valve stem after it is depressed locks it in this position and air will be admitted until it is manually unlocked. (See figure 94-6.)

94-5.

The inner surfaces of the eyepiece lenses may be covered with an antifog agent furnished with each goggle to resist fogging. If fogging then occurs, it may be alleviated somewhat by holding the canister valve open and pressing the rubber part of the goggles rapidly in and out, as in a bellows. The outside air thus drawn in the goggles through the canister washes down on the eyepieces and assists in clearing them. Obviously, this can be done only when the wearer's head is out of water. The canister valve should never be opened under water, for if it is, water will have access to the interior of the goggles. If in training or any other use of the goggles water does gain access to the canister, the chemical should be removed and replaced.

FIGURE 94-6.—Submarine escape goggle operating pressure equalizing valve.

94-6. METHOD OF FITTING ON THE "LUNGS"

The method of putting on and adjusting the "Lung" comprises the following steps:

(1) Remove "Lung" from cloth container.

(2) Tear off cellophane paper covering over rubber relief valve.

(3) See that metal shut-off valve in metal mouthpiece (housing) is closed.

(4) Put upper strap over the head. Secure snap hook on end of strap to D ring.

(5) Adjust upper strap so that level of mouthpiece is in alignment with wearer's mouth.

(6) Put belt around body and clamp it.

(7) Snap lower clips to trousers.

(8) Put nose clip on.

(9) Inflate with oxygen.

(10) Put rubber mouthpiece in mouth and open shut-off valve in metal mouthpiece.

(11) Breathe normally through the mouth.

94-7.

The nose clip should be adjusted so as to seal the nostrils completely. The mouthpiece should be so placed in the mouth that the lugs are held between the upper and lower teeth with the inside vertical flange or fin located between the lips and the teeth. It is neither necessary nor desirable to grip the lugs of the mouthpiece tightly. Upon reaching the surface the "Lung" may be used to keep the wearer afloat by closing the shut-off valve in the metal mouthpiece and closing the rubber relief valve at the bottom of the breathing bag by folding it and clamping it with the adjacent trouser clamp. (See figure 94-7).

Part 2. Buoy and Ascending Line

94-21. BUOY

(1) The buoy is cylindrical in shape and is 13'' in diameter by 15'' long. It is made up of solid layers of balsa wood. The slabs of balsa wood are specially treated during assembly to make them waterproof and resistant to decay. A center groove is formed about the circumference of the buoy for attaching the ascending line.

(2) The outside of the completed buoy is also waterproofed and then painted yellow with red ends. These colors are more easily distinguished at sea than others. Any repainting of the buoys should be done with yellow and red paint, first removing with sandpaper as much of the old paint as is necessary. *Do not use varnish or liquid paint removers as these will probably destroy the original waterproofing.*

94–22. ASCENDING LINE

(1) The ascending line is 500 feet long. It consists of a taffrail log line having a breaking strength of approximately 400 pounds. The line is secured about the buoy with two turns of the line, two half hitches and seized. The line at the buoy end is knotted with nine overhand knots, each spaced 10 feet apart, beginning at the buoy end of the line. The purpose of the knots is to facilitate the carrying out of the method of stage decompression, which in addition to the uniform ascent method of decompression is practiced in training. Also with markers on the line it is possible for the wearers of the "Lung" during their ascent to determine approximately how far they are from the surface after passing the 90-foot mark.

(2) Furnished with the line is a double-ended brass snap hook. This snap hook is required when the ascending line is used from vertical escape trunks. It is supposed to be secured in the bight of the ascending line after the buoy reaches the surface and then "snapped" through the pad eye on the outside of the trunk.

94–23. STRENGTH OF ASCENDING LINE

(1) The "Lung" inflated has a positive buoyancy. Consequently, when ascents are being made, the pull on the line is not from the buoy end but from the end secured to the boat. Tests to determine the strain exerted in the buoy line, as secured in the boat, with a varying number of men ascending the line, have been conducted in the submarine escape training tank at the Submarine Base, New London, Connecticut. The tests were made from 18-, 50-, and 100-foot depths. The results were as follows:

- One man ascending—10 to 15 pounds.
- One man stopped on line—8 pounds.
- One man stopped and one ascending—20 to 25 pounds.
- Two men stopped—16 pounds.
- Two men stopped and one ascending—25 to 30 pounds.
- Three men stopped—25 pounds.
- Three men ascending simultaneously—35 pounds.
- Two men ascending simultaneously—25 pounds.

(2) The line having a breaking strength of approximately 400 pounds, according to the above tests, would be capable of withstanding, without breaking, the strain exerted by 36 men on the line and ascending it simultaneously. However, under this condition the factor of safety in the strength of the line would be exceedingly small and if a tide is running, it is very probable that the combined stresses would exceed the breaking strength of the line. On the other hand, circumstances requiring this number of men simultaneously on the line could hardly exist. Assume, for example, that in a 200-foot depth of water, the men left the compartment as rapidly as 10 seconds apart. The space taken up by each man on the line would be about 5 feet. If the ascent is at a rate of about 50 feet per minute, the maximum number of men on the line at the time the first man and subsequent men reached the surface would be 24. As it will probably require from 20 to 30 seconds or maybe longer intervals between the emergence of the individual men, the strength of the ascending line is considered adequate to meet the most adverse conditions.

(3) An interesting fact disclosed by the abovementioned tests is that contrary to general belief a man, or men, stationary on the line will exert less strain on the line than when ascending. Apparently the greater strain exerted by progressive ascent is due to "Acceleration of buoyancy." Also, during ascent the expansion of air keeps the breathing bag fully inflated. When the men stop along the line, the air in the bag ceases to expand, the pressure within and without being equalized at that level. Also, when stopping, the volume of air in the bag is gradually decreased by the wearer's breathing whereby a certain percentage of oxygen in the air inhaled from the bag is absorbed by the body. It was found in these tests that a man's buoyancy when he inhaled and exhaled varied 3 to 4 pounds. The results of these tests also emphasize the necessity of securing *tightly* the inboard end of the line in the submarine escape compartment, or in the case of later-type boats, to the eyebolt outside of the escape trunks.

Part 3. Conditions Attendant on Submarine Sinkings

94–31. CAUSES CONTRIBUTING TO NECESSITY FOR ABANDONMENT OF VESSEL

(1) Accident to a submarine, necessitating its abandonment while submerged, may have been the result of explosion, collision, gunfire, or other cause. Whatever the cause, it must be assumed that the flooding of some major compartment will prevent the vessel surfacing under its own power. When such a condition develops, thought must be turned to escape. Delay means reduction in oxygen content, increase of CO_2, and the sapping of the vitality of the individuals.

(2) *Necessity for two escape compartments and special hull fittings.* On the assumption that the damage will divide the crew requiring them to retreat to the forward and after compartments, these compartments on all submarines have been fitted out with special appliances for individual escape. In addition to the fittings for individual escape, overhead escape hatches have been fitted with flanges to take the flanges of specially designed diving bells or rescue chambers by means of which collective rescue can be attempted.

94–32. FACTORS INFLUENCING ABANDONMENT OF VESSELS

The practicability of the rescue chambers for collective rescue depends upon various factors; such as the early location of the submarine by a surface ship, the early availability of the bells and a rescue vessel, the inclination, if any, of the submarine, and,

to a large extent, on the depth of water, and favorable weather conditions. These factors, and consideration of the detrimental effects on personnel of prolonged delay in making escape, should contribute largely to the decision as to whether the flooding of escape compartments for individual escape should be promptly begun or whether it should be deferred for a reasonable time awaiting collective rescue.

94–33. EQUALIZING PRESSURE IN ESCAPE COMPARTMENTS

(1) Before escape from submerged submarines can be made with individual escape devices, it is necessary that the air pressure within escape compartments or access trunks of such compartments be equalized with the external sea pressure to permit the hatches to be opened. It is also necessary that means be provided to prevent this air pressure from escaping or decreasing after the hatch door is opened, otherwise the compartment would become completely filled with sea water. In the after torpedo room this has been accomplished by installing a cylindrical telescopic skirt at the access hatch trunk. When the after torpedo room is to be used for escape purposes, the telescopic skirt is extended downward into the compartment. The after torpedo room can then be flooded and the air in the upper part of the compartment will be compressed as the water level rises. When the water level reaches the bottom of the skirt, it forms a seal and prevents escape of compressed air from the adjacent space through the hatch.

(2) When the hatch is opened, water will enter through the cylindrical skirt. The amount of water entering through the skirt depends largely upon the depth of submergence. In shallow depths the air pressure in the compartment, after flooding, will be equalized with the outside sea pressure before the water level in the compartment reaches the bottom of the skirt. Under such conditions, after the hatch is open, water will enter through the hatch until the water level in the compartment reaches the bottom of the skirt. At greater depths the water level will reach the bottom of the skirt when or before the air pressure is equalized. When the water level reaches the bottom of the skirt, it forms a seal and prevents escape of compressed air from the adjacent space through the hatch.

94–34. EQUALIZING PRESSURE IN VERTICAL ESCAPE TRUNK PREPARATORY TO ESCAPE

A vertical access trunk, which serves also as an escape trunk, is provided in the forward torpedo room. In effecting individual escape, the trunk is flooded to equalize pressure in lieu of flooding the compartment. The trunk will accommodate about 4 men simultaneously. After entering the trunk and closing the hatch between the trunk and the adjacent compartment, the trunk is flooded until air pressure in the upper part equals the sea pressure and the water level is above the level of the escape door. Mechanical means have been provided whereby this door can be closed by occupants in the submarine compartment below, after the successive groups of persons have left the trunk. The trunk can then be "blown" or the water in it can be drained into the compartment below, preparatory to entrance of the next group of individuals.

94–35. OXYGEN SUPPLY FOR INFLATING APPARATUS

Each escape compartment is provided with an oxygen supply for charging the "Lungs." The arrangements are similar and consist of an oxygen flask connected through a regulator to a manifold containing four outlets. Each outlet has a needle valve and a 6-foot length of rubber hose. A self-closing chuck of the Schrader type is fitted to the end of the hose. The manifold and charging hoses for the forward escape compartment are located in the escape trunk. In the after torpedo room, the location is near the lower end of the hatch trunk. An escape depth gage and a compartment pressure gage (caisson type) are installed in the vicinity of each charging manifold. Stowage facilities for the "Lungs" are provided in both torpedo rooms.

94–36. VARIABLE CONDITIONS ATTENDANT ON INDIVIDUAL ESCAPE

(1) Conditions attendant on accidental sinkings vary in individual cases. The necessity for abandoning the vessel by individual escape and the promptness with which it should be made will ordinarily depend upon: (a) the condition of the air in the boat, (b) inability to surface the vessel by means within it, (c) consideration of the probability of surface craft in the vicinity to pick up the men when they reach the surface, and (d) the possibility of rescue vessels locating the boat and effecting rescue by means of the rescue chamber before the air within the escape compartments becomes irrespirable.

(2) The above factors governing decision to abandon the vessel by individual escape are listed in the order of their importance and the first one, i. e., the condition of air in the boat or escape compartment, should be given the greatest consideration. An irrespirable atmosphere may be rapidly created by the increase of carbon dioxide, the liberation of toxic gases from flooded batteries, or by oxygen deficiency. Measures to maintain the atmosphere in respirable condition in accordance with the procedure outlined in chapter 38, Bureau of Ships Manual, should be instituted and carried out continuously until escape is made or rescue is effected. It is emphasized that if attempted individual escape is delayed until the first stages of asphyxia have developed, it will probably be too late to accomplish it successfully.

94–37. STEPS PREPARATORY TO ESCAPE

To abandon the vessel by individual escape, the following steps should ordinarily be taken:

(1) All available electric hand lanterns and flashlights, wrenches suitable for all nuts which must be removed, a maul or sledge for breaking sea connections, and a pinch bar should be assembled in the

escape compartments. This equipment should be stowed in escape compartments and periodic inspection made to insure that it is there at all times.

(2) Secure the bulkhead for watertightness.

(3) See that the telescopic skirt (Article 94-33) is in position and secured.

(4) Check up on oxygen supply and equipment. If the oxygen cylinder for inflating the "Lungs" is not completely charged and the contents are not sufficient for inflating every "Lung," a spare cylinder should be taken from the breathing line and made ready for use. See that the reducer on the cylinders is set at 60 p. s. i., that all valves in the oxygen manifold are open, and that oxygen is available in the manifold.

(5) Unlock the hatch and remove strongback if fitted.

(6) Secure light line (the end of the buoy line may be used) to the hatch, as a preventer, to keep the hatch from flying open while flooding.

(7) Have each man put on his "Lung" in accordance with the steps outlined in Article 94-5 and see that it is not faulty, canister full of soda lime, no obstruction to inhalation and exhalation through mouthpiece, flutter relief valve on bottom of breathing bag flexible and in good condition.

(8) Have buoy line ready and free for running. Men should remove shoes and coats. Do not remove socks, trousers, or shirt.

94-38. METHOD OF FLOODING

When the above steps have been carried out, the compartment is in readiness for abandoning. Procedures for flooding the after torpedo room and forward escape trunk during escape operations are described in the General Information Book which applies to the particular submarine.

94-39.

While preparing for, and during the process of flooding, all occupants of the compartments not engaged in the work should remain at rest, thus contributing to oxygen conservation and keeping the production of carbon dioxide (CO_2) at a minimum. If the submarine has been submerged for several hours, the combined effect of pressure and CO_2 already present or built up may become dangerous. The volume percent of CO_2 in inspired air that can be tolerated is inversely proportional to the absolute pressure. For example, at 66 feet or three atmospheres absolute pressure, one percent CO_2 would have the same effect as three percent at atmospheric pressure. Theoretically the same holds true for chlorine, should a trace or greater amount be present in the compartment.

94-40.

Before flooding the after torpedo room or forward escape trunk, CO_2 absorbent should be used as prescribed for submarine air purification. This will keep down the CO_2 content during preparations for flooding. It will continue to be effective for this, however, only as long as it remains dry. Also it affords no protection against chlorine. Accordingly, prior to flooding, especially if there is a detectable amount of chlorine present, the men should obtain "Lungs" and put them on. So far as concerns CO_2 as the pressure in the compartment rises, there will always be ample warning as breathing becomes very difficult before the effect of CO_2 under pressure becomes dangerous.

94-41.

To use the "Lung" as a respirator, remove the combination filler and respiration cap piece No. 7 (fig. 94-1) and the filler plug, shown on fig. 94-4. Put on the "Lung" as for escape, but breathe to and from it with filler plug removed. Under these conditions the surrounding air is drawn through the filler connection to the inside of the bag from where it is drawn up through the bottom of the canister and purified before entering the wearer's mouth. *Be sure, however, that the sealing plug is replaced tightly before inflating the apparatus with oxygen and using it for escape.*

94-42. AIR PRESSURE CREATED DUE TO FLOODING

When flooding, air in the compartment will be compressed. As the flooding proceeds, there will be built up in the upper part of the compartment an air pressure which eventually becomes equal to the pressure of the outside water. The occupants of the compartment breathe this compressed air. Consequently the air within their bodies becomes equalized in pressure with the pressure of the surrounding air. Danger from exposure to great air pressure depends not only upon the pressure reached but upon the length of time exposed to this pressure. Consequently, occupants should make their escape as quickly as possible once flooding has begun. Flooding of the after torpedo room, as it nears completion, may be hastened by allowing sufficient slack on the preventer line securing the hatch to permit the hatch to be opened about halfway. This will occur automatically when the pressure within becomes equalized with the outside sea pressure. At this stage the hatcn has a tendency to flutter several times, let air escape, and a corresponding amount of water in. Air will escape only at the rate water runs in. With the hatch about halfway open, a solid stream of water will run in until the water level within the compartment rises to the bottom of the skirt or just above it. At moderate depths water will not rise above the bottom of the skirt. At great depths, however, the water may rise a few inches above the bottom of the skirt. However, this should not cause alarm. Under any condition the air space surrounding the skirt will be sufficient for breathing purposes. Equalization of pressure in the compartment may also be hastened by utilizing the compressed air from the compressed air banks, bleeding the air simultaneously with the flooding.

94-43.

(1) Air pressure on the ears may cause discomfort to occupants of the escape compartment during

flooding. The inner ear has a small cavity which connects to the nose and throat through a small flexible tube known as the Eustachian tube. If this tube collapses or becomes blocked, air will not pass into the inner ear. Under such conditions, the pressure on the outer side of the ear drum will become greater, tending to force it in. This in turn causes more or less intense pain and increasing pressure may rupture the ear drum. This, however, is not considered a dangerous nor permanent injury. Usually the ruptured membrane heals within 4 or 5 days. Ordinarily air pressure can be readily equalized by sealing the nostrils with finger pressure and "blowing against the ear drums" by attempting to exhale forcibly with mouth and nostrils closed. This raises the air pressure in the mouth and throat slightly and tends to force the tubes open. The motion of chewing, or that of moving the lower jaw back and forth laterally, will also assist in opening the tubes and equalizing the pressure.

(2) The only other discomfort that may be experienced by some of the occupants as a result of subjection to rapid increase in pressure is a slight dizziness and shortage of breath When flooding at moderate depths, this will pass within a few minutes and symptoms if any should not interfere with the process of escaping. However, if the depth is 300 feet or more, it may be necessary to reduce the rate of flooding sufficiently to alleviate the symptoms.

94-44. STEPS PREPARATORY TO EMERGENCE FROM AFTER TORPEDO ROOM

(1) When flooding is completed, the depth of submergence should be noted from the sea gage and the caisson gage. The occupants stand in the air space surrounding the skirt of the hatch trunk. One man should charge his "Lung" with oxygen by pressing the air chuck of the oxygen hose momentarily over the oxygen inlet valve on the breathing bag. The greater portion of the bag should be submerged when inflating it, and it should be inflated until oxygen bubbles flow freely from the submerged rubber relief valve. The man should then duck under and go up the hatch skirt, sever the preventer line, if necessary, and throw the hatch wide open. He should then return to the compartment and pass the buoy up through the hatch skirt allowing the line to run until the buoy watches. Care should be taken to insure that the bitter end of the buoy line has been secured in the compartment before the buoy is released. Otherwise the buoy and line may be lost. After the buoy reaches the surface, the bight of the buoy line should be secured in the compartment to keep the line taut during ascent of the crew.

(2) The above procedure, in general, completes the preparations necessary for individual escape from the after torpedo room. The occupants of the compartment next charge their "Lungs" with oxygen in accordance with the method described above. There are four outlets to the oxygen manifold and four men can charge their "Lungs" simultaneously. Charging the "Lungs" should be accomplished rapidly and continuously so that individual emergence can be effected at about 1-minute intervals.

94-45. EMERGING FROM THE VESSEL

After charging the "Lungs" the occupants duck under the hatch skirt, follow the ascending line through the hatch, and ascend consecutively one after the other slowly up the line at a uniform rate until they reach the surface.

94-46. PRECAUTIONS WHILE PASSING THROUGH HATCH

Passage through the hatch should be made cautiously to avoid fouling hatch projections or possible deck wreckage. As the feet clear the hatch, place the ascending line between the feet or bend one leg around the line and ascend the line at a rate of about 50 feet per minute. This rate will be approximately obtained if the ascent is made slowly hand over hand.

94-47. POSITION WHILE ASCENDING BUOY LINE

(1) The reason for placing the ascending line between the feet or bending a leg around it during ascent is that it not only slows up the ascent but assists the man in keeping his feet down. Do not permit the feet to float out so that the body assumes a horizontal position or a position in which the rubber relief valve is above the level of the top of the breathing bag, for under such conditions the oxygen in the breathing bag will be pressed out and lost: While under such conditions the bag will be automatically reinflated on the man's gaining an upright position and continuing his ascent, the air in the reinflated bag will not be as rich in oxygen.

(2) If the sea is rough, the rise and fall of the waves may cause some discomfort when shallow depths are reached in the ascent. It is urged, however, that even under these conditions the continuation of ascent be slowly made.

94-48. PHYSIOLOGICAL EFFECT OF ROUGH SEAS

(1) After reaching the surface, keep the mouthpiece in the mouth and close the rubber relief valve by folding it over and clamping it with the right hand trouser clamp. Fig. 94-7. Note whether the breathing bag is fully inflated. If it is, close the cut-off valve in the metal housing and remove mouthpiece from the mouth. If it is not fully inflated, completely fill it by exhaling forcibly into it. Then close cut-off valve. The apparatus will then support the wearer on the surface. The breathing bag should not be allowed to become deflated. Reinflate from time to time as may be necessary by forcibly exhaling into it.

(2) Should it become necessary for the crew to remain afloat for some time, it is advisable that they maintain proximity to each other. Nothing is furnished at the present time to facilitate this but it is suggested that a line improvised from the men's clothing would contribute to maintaining contact and insure assistance that may be needed by weaker members of the crew.

94–49. USE OF TORPEDO TUBES AS ESCAPE HATCHES

(1) Torpedo tubes may also be utilized, in an emergency, for individual escape. In using the torpedo tubes, all preparations governing escape from escape compartments, as outlined in the foregoing, should first be made. See that the torpedo loading hatch is set down tight and that the ventilation ducts are closed tight. Open the outer tube door, disconnect the interlocking gear and block it so that the cover

FIGURE 94–7.—The "Lung" as a life preserver. When using valve and relief valve, folding latter and clamping it with "Lung" to keep afloat after reaching surface, close cut-off trouser clamp.

cannot move. It is preferable that the upper tube be used. When these steps have been taken, open the inner door, standing well clear as the door swings open with the inrush of water. When flooding is complete, send out the buoy line. This can be done very easily if air is available. Place buoy in the tube with slack line and turn on air. The outward flow of water and air will carry the buoy clear of the tube. If there is no air available, the buoy may be pushed through the tube. Discontinuing of pull on the line and consideration of the amount of line which has payed out will be indicative of the buoy's watching at the surface. When the buoy reaches the surface, pull in any slack that is in the line and make the line fast so that it will ride along the upper wall of the tube where it can be readily used as a grab line by the men for pulling themselves along hand over hand out of the tube.

(2) When the above arrangements have been completed, each man in turn charges his "Lung", first closing off the flutter valve by using one of the holding clips. This is done to prevent loss of gas when the wearer is lying in a horizontal position in the tube. The wearer then enters the tube head first, back down, grasps the line and pulls himself along hand over hand until clear of the tube. Assistance in starting the man through the tube by others in the compartment will hasten the evacuation of the compartment.

(3) As the man's head emerges from the tube into the open water, his body will tend to rise following the lead of the buoy line. It is not difficult then to move out and up the line. *However, when completely out of the tube and clear of the boat, it is absolutely essential that a momentary stop be made to unseal the rubber relief valve by unclamping and removing the trouser clamp from the valve.* The clamp should then be clamped to the trousers.

(4) After a man starts through the tube, he should bear in mind that there are others to follow him and he should not linger in the tube or around the mouth of it.

94–50. EMERGENCE FROM VERTICAL ESCAPE TRUNK

(1) The access trunk above the forward torpedo room is fitted with a door and equipped for use as an escape compartment. The procedure of individual escape is the same in principle as that governing escape from the after torpedo room.

(2) The trunk has a capacity for about four men. While the trunk must be flooded to equalize sea pressure, it affords a means of emergence without the necessity of flooding the forward torpedo room and, consequently, without subjecting the men to prolonged high pressure and cold water.

94–51. ENTERING THE VERTICAL ESCAPE TRUNK PREPARATORY TO FLOODING

In escape from the forward torpedo room, escape equipment should be prepared as prescribed in article 94–37. When this has been done, the first group of men selected to make the ascent with their "Lungs" in place should enter the trunk through the bottom hatch, which is closed after them, either by the men themselves or by the men in the compartments below.

94–52. FLOODING THE TRUNK

The flooding of the trunk should be completed as rapidly as possible. As the flooding proceeds, it will compress the air in the upper part of the trunk. While the flooding is proceeding, undog the door so that it will open when the pressure in the trunk equalizes with the outside sea pressure. When the water level reaches the top sill of the door, it will form an air seal which, after the pressure equalizes, will prevent escape of the compressed air to the

sea after the door is opened. If the depth is sufficient to cause the water level to rise above the top sill of the door before the pressure equalizes, compressed air if available should be used to keep the water level at the top sill. In shallower depths, the water level may not reach the top sill when the pressure is equalized. Under this condition, additional water will run in when the door is opened, but the amount will be limited to that which will bring the level of the water in the trunk to the top sill.

94-53. RELEASING THE BUOY LINE AND SECURING INBOARD END OF LINE

After the door is swung open, the buoy and ascending line should be sent out, first being sure that the inboard end of the line is secured in the trunk. Keep a hand on the line, as it pays out, so as to determine when the buoy has reached the surface, allowing enough slack for a tide pull if there appears to be any. A double-ended snap hook is provided with the line. When the buoy surfaces, a little slack is pulled down and a loop made in the bight of the line. Make sure that the hitch will not slip. When this is done, hook the snap hook into the loop. Then with one hand reach out of the door and snap the snap hook in eye of the pad eye which is located on the outside of the trunk about nine (9) inches above the door and to the off side of the door hinges. When the line has been thus secured, draw in the slack, cut the line off inboard of the outside package, and stow the loose portion away. When cutting the line, cut it sufficiently close to the pad eye so that the resulting free end will not hang in the doorway *but take extreme care not to cut the buoy end of the line.* See that flooding valve is closed.

94-54. EMERGENCE FROM ESCAPE TRUNK

The procedure (article 94-54) should consume only a few minutes. When it is completed, each man should inflate his "Lung", duck one after another through the door, and ascend the buoy line in the same manner as prescribed for ascents from the after torpedo room (articles 94-45 to 94-48 inclusive). The ascent should be at a slow uniform rate *and as far as practicable not over fifty feet per minute.*

94-55. EMERGENCE BY GROUPS

Emergence as described above should be made as rapidly as possible by successive groups until the compartment below the trunk is completely evacuated. After each group leaves the trunk, the side door can be closed by mechanism operated by the occupants remaining in the compartment below and the trunk "blown" and vented and the communicating hatch reopened preparatory for entrance of the next group of men. In the absence of telephonic communication, a set of signals (sound) should be arranged for, prior to entrance to the trunk. The last man emerging from the trunk should signal his departure.

94-56. CLEARING DEBRIS IN VICINITY OF TRUNK DOOR

If, as a result of the accident, there should be any wreckage obstructing clear passage outside of the door, it should be cleared away, if possible, by the first group emerging from the trunk, before ascending to the surface. If necessary, return to the trunk, and thence to the compartment for gear to do this. While the "Lung" was not designed as a diving apparatus, it will, with a full initial charge, permit normal respiration for five or six minutes at any depths not exceeding the depth at which it was initially inflated. If necessary, a man can work for about five minutes at a time outside of the trunk and then return to the trunk, recharge his "Lung", re-emerge and continue the work. Under such conditions, however, it will be absolutely essential that he hold himself down to the deck as otherwise he would float rapidly to the surface with detrimental results. If such work has to be undertaken, the man should be provided with a short improvised life line, secured to the outside of the trunk. When the work is completed, this line should be removed and stowed away to insure that it does not foul the door and prevent its closing.

94-57. PRECAUTIONS TO BE TAKEN AGAINST EXCESS CO_2 IN ESCAPE TRUNKS

(1) The air pocket formed in the trunk by flooding is comparatively small. Unless compressed air is available and has been used continuously to keep down the water level (see article 94-53), breathing for extended periods without the "Lung" will probably increase the CO_2 content to dangerous proportions in the trunk. If compressed air is used to keep down the water level, the excess air and its escape below the upper sill of the door will probably dilute the CO_2 in the pocket sufficiently to keep the air respirable.

(2) If the air pocket cannot be ventilated as described above, and it becomes necessary for any reason to prolong the stay in the trunk, the occupants should wear and breathe into and from the "Lung" reinflating it at frequent intervals—every 3 or 4 minutes. If, for any reason after emergence it becomes necessary for any of the men to return to the trunk, after getting back in the trunk they should reinflate the "Lung" without removing the mouthpiece from the mouth.

(3) If when the flooding of the trunk is in progress there are any symptoms of excess CO_2, occupants of the trunk should start immediately breathing through the "Lung". Excess CO_2, if breathed, will be evidenced by increased respiration; i. e., the breathing will become fast with perhaps a tendency to gasp and possibly accompanied by growing dizziness.

(4) The length of the oxygen-charging hoses in the trunk should be limited to that which will insure them from hanging outside of the door or being capable of being pushed up behind the hinges.

94–58. DECOMPRESSION

(1) When the Navy submarine escape apparatus was first adopted, the prescribed method of use required stops at certain levels during ascent up the buoy line for decompression. Under the most adverse conditions of submarine accident, it is possible that all of the crew might have to retreat to a single escape compartment. In this case a portion of the crew might be exposed to high-pressure air and cold water for prolonged periods unless they could emerge from the compartments more rapidly than is permitted by the stop method of decompression.

(2) Subsequent training and experiments showed not only the necessity for decompression of subjects exposed to high pressures but definitely indicated that a too rapid ascent produced air embolism with consequent likelihood of lung rupture. Extensive investigations, however, indicated that for relatively short exposures decompression could be satisfactorily effected with a slow uniform rate of ascent, and that possibility of air embolism could be prevented if the maximum rate of ascent is approximately fifty (50) feet per minute.

(3) The method of slow uniform ascent has been adopted with the realization that it may not be as effective as the previous stop method of decompression for preventing contraction of bends if conditions are such that personnel are exposed to high pressures for long periods before emergence. However, it permits consecutive individual emergence at a rapid rate, eliminates the necessity for remembering decompression tables, and provides a reasonably safe method of ascent without discrimination as to the order of individual egress. It is believed that these advantages more than offset the probably greater factor of safety afforded by the stop method of decompression. For further information on this subject see articles 94–91 to 94–107, inclusive. In conclusion, it is desired to emphasize the necessity of making *slow* ascents up the buoy line to permit proper decompression of the men and to prevent deleterious results of expanding internal air pressures in the body.

Part 4. Stowage, Care, and Periodic Inspection of "Lungs" Aboard Ship

94–71. EXAMINATION OF "LUNGS" PRIOR TO STOWAGE

Primarily "Lungs" are issued to submarines for individual escape in the event that the submarine is disabled and sunk and cannot surface under its own power. To be effective for this use, it is essential that the "Lungs" be maintained in good working condition at all times. They should be carefully examined before stowage aboard and periodically during stowage to insure the continued functioning of their constituent parts. If they have been previously used for training or any other purpose, they should be carefully inspected and, if necessary, reconditioned before being restowed. New "Lungs," when received, should be carefully examined to insure the satisfactory operation of all the constituent parts, as follows:

(1) That the rubber mouthpiece contains both rubber lugs and that all parts of same are flexible and in good condition.

(2) That the rubber relief valve is intact and functions satisfactorily. In new "Lungs" this may be ascertained by exhaling forcibly into it and observing whether the relief valve opens on exhalation and closes on inhalation. The breathing bag not being initially inflated with oxygen, this test should be of short duration—not to exceed four breaths—otherwise there might be created a deficiency of oxygen in the breathing bag. If the rubber relief valve is badly crimped, hardened, or cracked, replace it.

(3) That the canister wire mesh screens are not clogged with soda lime, water, or rust. In new "Lungs" this may be ascertained by breathing normally into and from the "Lung." Obstructions will be evidenced by increased or excess resistance to inhalations. In this test the canister should be full of soda lime as received. The breathing bag can be inflated with oxygen or not, at the wearer's option. The sealing plug on the front receptacle may be removed as an alternative to charging the bag with oxygen. If excess resistance to exhalation is noted, the soda lime should be removed from the canister, the canister screens cleaned as described in article 94–76 (8), and the canister then refilled.

(4) That the rubber breathing bag is intact and contains no holes, tears, or weak spots.

(5) That the cut-off valve in the metal mouthpiece when fully opened does not obstruct breathing. This may be determined by closing the relief valve with the fingers and, while closed, inflating the breathing bag by forcibly inhaling into it. The nose clip should be left off in this test and inhalations made through the nostrils

(6) That the mica disc valves in the metal mouthpiece which control the directional flow of the inhalations and exhalations are functioning properly. Ordinarily this can be determined without removing the mouthpiece from the apparatus by breathing normally into it and listening to the reaction of the valves which after each inhalation and exhalation reseat themselves with a "clicking" sound on their metallic seats. Inoperative valves will be evidenced by obstruction to inhalation or exhalation. If there is any doubt as to their proper functioning, the metal mouthpiece should be removed and tested in accordance with the procedure outlined in articles 94–76 (2) (3).

(7) That the canister is completely filled with soda lime.

(8) That the nose clip is attached to the metal mouthpiece by its leather thong and is intact with its two rubber nose pads.

(9) That threads of all nozzles and connections are lubricated as prescribed in article 94–76 (4).

(10) That goggles are in good condition and that

the lenses of same are clean and not cracked or broken.

(11) That the "Lung" complete is properly placed, when stowed in its cloth container and secured therein, in such manner that there will be no folding or disarrangement of the rubber parts of the apparatus. Before replacing the "Lung" in its cloth container, see that the cellophane bag covering the relief valve is replaced and the cut-off valve in the metal mouthpiece is closed. This prevents the entrance of air to canister and prevents the deterioration of the soda lime which may otherwise be detrimentally affected in the course of time by moisture.

94–72. "LUNGS" FOR TRAINING

Due to constant alternate wetting and drying and abusive handling, "Lungs" used for training purposes suffer a progressive deterioration that manifests itself in clogged and corroded screens and fittings, frozen connections, etc. Therefore, "Lungs" issued to submarines shall not be used for training purposes. Submarine tenders will provide a sufficient number of "Lungs" for training purposes to enable the personnel of the individual submarines to undergo training without recourse to the vessel's outfit of "Lungs."

94–73. PERIODIC INSPECTION OF LUNGS

Rough handling is likely to result in damage to the "Lungs" as follows:

(1) Deformation of the metal mouthpiece (metal valve housing) interfering with proper functioning of the mica disc valves.

(2) Developments of leaks in the top of metal valve housing.

(3) Broken or bent cut-off valve stem.

(4) Dented or ruptured soda lime canister.

(5) Broken or bent wing of the metal mouthpiece butterfly connection.

94–74. "Lungs" used for training purposes should be inspected for proper operation and continued good condition of their constituent parts as enumerated above before each ascent. Any of them containing or developing defects should be replaced and laid aside for repairs. After each day's training, the "Lungs" should be thoroughly examined in accordance with the procedure outlined in paragraph (1) above, the soda lime removed from the canister and discarded, the canister and its screen thoroughly washed and blown, and the "Lungs" dried as prescribed in article 94–71.

94–75. QUARTERLY INSPECTION

(1) The atmospheric condition aboard submarines, the constant vibration to which the stowed "Lungs" are subjected, and other conditions make it desirable for the "Lungs" to be examined quarterly and thoroughly inspected annually. The quarterly examination should be similar to that accorded new "Lungs" when received, see article 94–71. Rubber mouthpieces, rubber relief valves, soda lime in the canister, and the straps and clothing clamps should be particularly observed. If the rubber parts mentioned have become hardened and lack elasticity or they are checked or cracked, they should be replaced. If the rubber relief valves have become permanently deformed to the extent of not properly releasing excess air in the breathing bag, they should be replaced. If the lugs on the rubber mouthpiece have become hardened or torn or either of them missing, the rubber mouthpiece should be replaced.

(2) If the soda lime in the canister appears damp, dirty, or pulverized, it should be renewed, the canister first being thoroughly cleaned in accordance with the procedure outlined in article 94–76 (8). The cellophane bag or covering over the relief valve, if it is removed for this inspection, should be replaced before returning the "Lung" to its cloth container. Any tears or holes in the cloth container should be mended.

94–76. ANNUAL INSPECTION AND REPAIRS

Once a year, dating from the time an outfit of "Lungs" or any part of an outfit is received on board, the "Lungs" on each submarine should be thoroughly inspected, tested, and, if necessary, repaired in accordance with the following procedure:

(1) *Disassembling "Lung."* Remove metal mouthpiece, combination sealing cap and wrench, canister filling plug, and oxygen inlet valve cap. The metal mouthpiece can be removed by unscrewing the winged connecting nut. The other metal fittings mentioned can be removed by unscrewing them from their respective connections.

(2) Test mica valves in metal mouthpiece and examine valve housing and cut-off valve for defects. Do not endeavor to disassemble the metal mouthpiece to observe the operation of the valves. Proper functioning of the valves will be indicated by a "clicking" sound as the valves unseat and reseat themselves on inhalation and exhalation through the mouthpiece. In some cases the clicking of the valves in the mouthpieces may be hardly perceptible. Their silence, therefore, should not be construed as an indication of improper functioning.

(3) As an additional test, plug the exhalation exit with the thumb and exhale into the mouthpiece. If a normal exhalation cannot be forced through the mouthpiece, the inhalation valve is seating properly. With a piece of light rubber tubing or other airproof material cover the circular airports in the lower part of the metal mouthpiece and endeavor to inhale through the mouthpiece. If air cannot be drawn through the mouthpiece, the exhalation valve is properly seating. In testing the inhalation valve there may at a certain point be heard a chattering of the valve. As the valves are exceedingly sensitive, not much pressure is required to lift or seat them. If they chatter, it is due to the fact that the force of the exhalations and the consequent pressure built up over and around the edges of the valve are greater than those that occur when the mouthpiece is connected to the canister. In other words, the force of the exhalation used in testing the valve is greater than that of exhalations made into the "Lung" in

its entirety, and this back pressure, as it were, may, in some cases, have a tendency to lift the edge of the inhalation valve and produce chattering. In no case, however, has it occurred when the mouthpiece is connected to the canister and the "Lung" normally breathed in and from. Consequently, any chattering of the valves in the mouthpiece should not be interpreted as a defect nor an indication of leakage. Even if leakage did occur in these valves, the result would not be serious, even potentially, for it will be noted that there is practically no dead air space between the wearer's mouth and the canister. Leakage of the valves will only result in the exhalations as well as the inhalations being passed through the soda lime canister, with, of course, an increased resistance to the exhalations equal to the resistance of the chemical in the canister to the passage of air.

(4) *Lubricating cut-off valve.* Remove the cut-off valve stem in the metal mouthpiece and see that it is free from verdigris. Lubricate the valve and its bearing surfaces in the mouthpiece with a thin layer of glycerin or with the special lubricant provided in the repair kits for this purpose. Reassemble the valve, care being taken to insure that the valve lever leads in the proper direction for opening and closing the valve. These valves are so made and the levers so arranged that when the valve is closed, the end of the lever projects into or fouls the vertical flange on the rubber mouthpiece. It was constructed thus to insure that the wearer of the "Lung" opened the cut-off valve before starting his ascents, there being a tendency among novices in the use of this apparatus to forget to open the valve. Obviously the "Lung" cannot be breathed into unless the valve is opened, and as at present designed it has to be opened before the user can insert the mouthpiece in his mouth.

(5) *Inspection and renewal of gaskets.* Inspect and if necessary renew the metal mouthpiece gaskets in the circular key on the end of the exhalation duct and inside of the winged nut connection.

(6) Renew gaskets of canister filling plugs and those of the plugs on bottom receptacle.

(7) *Inspection of canister.* Dump soda lime and inspect soda lime canister for dents, etc. This canister is not removable and attempts to remove it from the breathing bag should not be made. If the canister is badly dented or otherwise deformed, it will be evidenced by feeling it through the breathing bag material.

(8) *Cleaning of canister.* Thoroughly clean out the soda lime canister by washing it with water to clear the internal wire mesh screens of any clinging soda lime or rust. One screen is at the bottom and the other near the top of the canister. The canister should be washed with a hose of sufficiently small size to be inserted in the canister filling hole. The water should be under slight pressure and the stream directed alternately to the upper and lower screens of the canister. Wash the canister thus through the canister filling plug connection letting the water run out through the rubber relief valve on the bottom of the breathing bag.

(9) *Inspection of straps and clips.* Inspect and check all straps and clips to insure their good condition.

(10) *Repairing of "Lungs".* Inspect breathing bag and rubber relief valve for deterioration. If breathing bag is torn or otherwise defective, replace apparatus. If relief valve has deteriorated or is otherwise defective, replace it provided breathing bag is in usable condition.

(11) *Repair of metal mouthpieces not to be attempted by ship's force.* Repair any defects that may have developed, so far as it is within the capacity of the ship's force and the repair kit which is furnished to each submarine for this purpose. The exception to this is the metal mouthpieces. The metal mouthpiece is considered to be the most vital part of the "Lung". When they are manufactured, they are subjected to an internal air pressure of 14 p.s.i. to insure their strength and airtightness. Their tops are soldered on by a method which precludes the possibility of the attendant heat warping the mica disc valves mounted therein. Consequently the removal and the resoldering of these tops for the purpose of examining or replacing the mica disc valves and subsequent air testing of the mouthpiece to insure its tightness are considered to be beyond the capacity of the ship's force. If any defects develop in a metal mouthpiece, the mouthpiece should be replaced from the spares carried in the repair kits. Defective mouthpieces should be turned over to the tender. The Bureau will advise the tender as to the ultimate disposition desired for the defective or damaged mouthpieces upon receipt of information that they are on board and the number of them involved.

(12) *Testing breathing bag for leaks.* With the canister of the "Lung" empty but with the mouthpieces and all plug connections tightly secured in place, submerge the "Lung" vertically in water and inflate with air through oxygen inlet until the air escapes through the rubber relief valve on the bottom of the breathing bag. See that relief valve exhausts the air readily. Fold and clamp the relief valve, close the cut-off valve in the metal mouthpiece, and partially inflate the breathing bag. Submerge the partially inflated bag horizontally and observe whether there are any bubbles denoting the presence of leaks. In this test there may be observed small bubbles forming or rising after comparatively long intervals. These need not necessarily result from leakage but are usually due to escape of external air that has been entrapped in some of the irregular contours or pockets of the bag or fittings when the "Lung" was submerged.

(13) *Drying the "Lungs."* After the above steps have been taken, remove metal mouthpiece and hang the "Lungs" vertically, tops down, with the slit in the rubber relief valve forcibly held open, for several hours to dry. After drying, each "Lung" and its

metal mouthpiece should be blown out with dry compressed air, supplied from a hose of small enough diameter to permit insertion in the canister nozzle, canister filling connection, and the air ducts of the metal mouthpiece. This is to insure the screens of the canister and the interior of the metal mouthpiece being absolutely dry and unclogged before refilling the canisters with soda lime, assembling the "Lungs", and storing them.

(14) *Refilling the canister with soda lime.* After the interior of the canister is thoroughly dry, refill canister with fresh soda lime. Each canister holds approximately 490 cubic centimeters. The canisters should be completely filled, and during the operation of filling it is desirable that they be held horizontal and shaken or vibrated to settle the soda lime and insure a complete filling. After filling, replace the sealing plug tightly to insure against leakage of air, also secure the combination sealing cap and wrench.

(15) *Reassembling "Lung."* Lubricate threads of breathing bag filling connection, respirator receptacle, and plugs for same, using lubricants furnished in the repair kit. See that gaskets are in place and in good condition. Screw in the plugs of all fittings tightly. See that gaskets for winged nut connection of metal mouthpiece and gasket for seat at the base of exhalation air duct of metal mouthpiece are in place and in good condition. Lubricate lightly the threads of the winged nut and the threads of nozzle on the breathing bag to which the metal mouthpiece connects. Connect metal mouthpiece to breathing bag by means of the winged nut. Tighten the winged nut sufficiently to insure an airtight connection, taking precautions during this operation to insure that the rubber mouthpiece leads in the proper direction. The end of the exhalation duct is provided with shoulders which prevent the rotation of the mouthpiece. Inspect rubber mouthpiece and nose clip and see that they are properly secured to "Lung."

(16) *Final test of "Lung."* Close cut-off valve and rubber relief valve and inflate once with oxygen or compressed air to insure proper working of oxygen inlet valve on the breathing bag. If the valve does not function entirely satisfactorily, put in a new plunger and retest. Deflate "Lung" by opening the relief valve. Replace oxygen inlet valve cap to prevent entrance of dust or foreign matter to the valve plunger. Renew cap if damaged or missing. Renew if necessary the cellophane cover over the relief valve.

(17) *Placing the "Lung" in its cloth container.* After the above inspection and tests the "Lung" in its entirety (together with one pair of goggles) should be replaced in its cloth container. The container should be in good condition. Any tears or holes in it should be mended. The cloth containers are provided with a lashing on the interior of the container near the top and a drawstring on the top. Hold the "Lung" in a vertical position by grasping the metal mouthpiece with one hand, lower it, with the bottom of the breathing bag down, into the container until the mouthpiece is slightly below the top of the bag. Still grasping the metal mouthpiece with one hand, take the other hand and draw the drawstring inside of the container sufficiently tight to support the "Lung." When tightening the drawstring, care should be taken that the weight of the "Lung" is borne by the metal mouthpiece. This will be insured if the pressure of the drawstring is applied directly under the metal mouthpiece at the junction of the winged nut and breathing bag. Suspending the "Lung" in the cloth container prevents its slipping down into the container under its own weight and deforming the bottom of the breathing bag and rubber relief valve when stowed. When the apparatus has been secured in the cloth container, the upper drawstring should be drawn tight with a sliding knot. The loose ends of the upper drawstrings should then be tied with about a 2-inch bight. The "Lungs" are then ready to be stowed.

The "Lungs" should be secured between the frames of the submarine escape compartments by looping the bight of the drawstring over the hooks provided for this purpose on and between the frames in the compartment. "Lungs" may be stowed one on top of the other to the depth of the frames if the spaces between the frames are provided with the light steel plates or wire mesh to support the "Lungs" overhead. They should never be stored on their sides, tops, or bottoms.

94-77. STOWAGE ABOARD SHIP

(1) Stowage is provided on submarines for the vessel's allowance of "Lungs." The allowance for each torpedo room consists of one lung for each person on board plus 10 percent for spares.

(2) In the forward torpedo room, the "Lungs" should be stowed as closely to the trunks as practicable, without interference with the operating gear or the permanent fittings in the compartment. They may be stowed in the readily accessible lockers or spaces that have been provided.

(3) In the after torpedo room, the "Lungs" should be stowed in readily accessible overhead spaces between the frames and as near to the escape hatch and the oxygen supply as is possible to have them without interference with operating gear or permanently installed fittings. The "Lungs" should be hung by their drawstrings from hooks welded to the frame for this purpose, and the "Lungs" supported by light steel plates rolled to conform to the curvature of the frames and installed between them in such a manner as to be readily removable.

94-78. STORAGE ASHORE

Used "Lungs" stowed ashore should be subjected to the same inspection and tests prescribed above for those aboard ship before reissue. They should likewise be as carefully placed in their cloth containers. "Lungs" should be stowed in dark, cool, dry, and well-ventilated spaces, preferably in the paper cartons in which they were originally shipped.

Storage ashore may be on shelving in storerooms, provided the atmospheric conditions are satisfactory. They should, under these conditions, be stowed horizontally. They may be stowed one on top of the other to a maximum of five layers.

94-79. LUBRICATION OF "LUNG" FITTINGS

(1) "Lung" fittings are made of anodized aluminum. While they are corrosion-resisting, interlocking threaded part may be susceptible to "freezing" when stowed for long periods after use, unless the threads are properly lubricated before stowage.

(2) While glycerine, vaseline, and other ordinary petroleum greases applied to the threads of these fittings tend to prevent freezing, it has been found that better results are obtained with special lubricants made of vegetable oils and containing finely ground emery. These lubricants are contained in the "Lung" repair kits, in compressible tube containers, with instructions for their use. They should be used in lubricating the threads of fittings on all "Lungs." Other lubricants are not only inferior when used on anodized aluminum but may tend to introduce disagreeable and possibly harmful fumes into the breathing system. A drop or two of glycerine, smeared between the slits of the rubber relief valve, will prevent the internal faces of the valve from sticking together during storage.

94-80. REPAIR KITS

Each submarine and submarine tender is furnished with a standard repair kit containing all of the tools, spare parts, and materials necessary for effecting minor repairs to the vessels' outfits of "Lungs." This kit is made of metal and is called for on the allowance list of each submarine and tender. It should be maintained on board at all times completely equipped. When spare parts and materials are used to effect repairs, a requisition should be submitted for an equivalent number of parts, amount of material, etc., to replenish the kit. The tools, spare parts, and materials obtained in each kit are as follows:

Quantity	*Name*
2	Metal mouthpiece
5	Rubber mouthpiece
25	Rubber flutter valve
2	Oxygen admission valve complete with retainer
12	Inside valve for oxygen admission valve
2	Canister plug
2	Combination canister and respirator plug
12	Nose clip
12	Strap for nose clip
24	Small gasket for mouthpiece
24	Large gasket for mouthpiece
24	Canister plug gasket
24	Combination canister and respirator plug gasket
12	Closing valve springs
36	Pin for spring retaining nut
6	Screw, set
5 yd.	Roll of adhesive tape
1 oz.	Tube rubber cement
¼ lb.	Spool copper wire
2 oz.	Soapstone in container
1 oz.	Tube white petroleum
2	¼ oz. jars aluminum wax
5 yd.	Roll rubberized tape
½ oz.	Tube grease for closing valve
2	Spanner wrench for mouthpiece wing nut
2	Combination canister and respirator plug wrench
2	Securing chain for plug

Part 5. Submarine Escape Training

94-91. TRAINING TANK

(1) The "Lung" is of such simple construction and operation that its proper method of use can be mastered within a few minutes. Properly used, it affords a means whereby occupants may emerge from sunken submarines and ascend to the surface with reasonable safety. However, the success of any adopted method of submarine escape will be contributed to or hampered by the physical and psychological reactions of the entrapped personnel to the particular conditions encountered. The possibility that personal reaction will become a controlling factor is largely eliminated by thorough training in the use of the "Lung" under conditions simulating as closely as possible those attendant on actual sinkings and escape. For this purpose specially designed training tanks are used at the submarine bases at New London, Connecticut, and at Pearl Harbor. The system of training forms a part of the standard qualification for submarine duty for all submarine personnel.

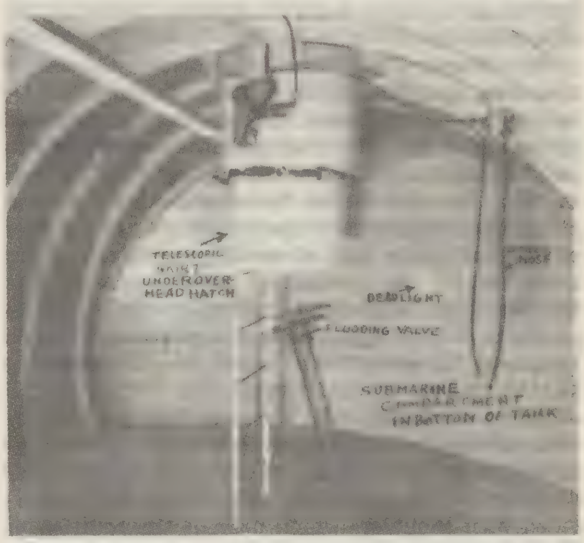

FIGURE 94-8.—Submarine escape training tank at Submarine Base, New London, Conn. Telescopic skirt in one end of submarine compartment at bottom of tank. Wheel to flooding valve in background.

(2) *Description of tanks.* These tanks are approximately 134 feet high from foundation to roof. The stack is about 18 feet in diameter and holds approximately 280,000 gallons of water at a depth of 100 feet. Through side-escape locks, personnel can enter the water at levels, 18 feet and 50 feet deep respectively, and ascend to the surface. A replica of a submarine compartment, Fig. 94-8, with an overhead escape hatch and also a vertical escape trunk is built into the bottom of the tank.

(3) The house joins the tank at its base and is called the equipment house. It contains the filters, chlorinators, and water heating systems used to maintain the water in the tank free from bacteria and to keep it at a comfortable temperature. A recompression chamber for preliminary qualification of the men "for "Lung" training and for treatment of compressed air illness in case of contraction of bends also forms a part of this equipment.

94-92.

Inside of each lock there is a door which communicates with the tank. The doors are equipped with the rapid acting locking arrangement as installed on the bulkhead doors and vertical access trunks of all submarines. The side locks have a capacity for four or five men. The flood and vent valves are also installed as on submarines. The group of men to make the ascent enter the lock. Flooding water enters at the bottom of the lock, from the tank and as it rises, it compresses the air in the upper part of the lock. When the air pressure in the trunk equalizes with the outside water pressure in the tank at the lock level, flooding automatically ceases. The door communicating with the tank is then opened. Water enters through the door until the level in the lock reaches the top sill of the door. It there forms a seal preventing escape of the compressed air. After the pressure in the trunk is equalized with the tank water pressure, the door of the trunk leading into the tank is opened. The buoy is then sent through the door to the surface of the water in the tank. The men having in the meantime donned their "Lungs" charge them with oxygen and duck through the communicating door and ascend the line in the tank.

94-93.

(1) The submarine compartment will accommodate as many men simultaneously as the escape compartments in the submarines. Access to the compartment is gained through a door leading off a platform installed in the equipment house. After entering the compartment, the access door is closed and dogged and flooding started. Like the side locks, flooding water is drawn from the water in the tank. As the water rises, it forms an air pocket in the upper part of the compartment. The bottom of the cylindrical skirt under the escape hatch forms a seal with the water and prevents escape of the entrapped air when the pressure equalizes and the hatch opens. The process of emerging from the compartment is the same as that described in the foregoing.

(2) In escaping from the compartment by way of the vertical escape trunk only the trunk is flooded. The process of flooding and emerging from the trunk is the same as that described in articles 94-51 to 94-56 inclusive for emerging from the vertical escape trunks on submarines.

94-94.

The loft, side locks, bottom submarine compartment, and equipment house are provided with a telephone system which permits communication between the respective stations mentioned. In addition, the side locks and the bottom submarine compartment have exterior telephones by means of which observers on the platforms can communicate with the occupants of the locks and compartment and thence with attendants in the loft if necessary.

94-95.

The locks and the bottom submarine compartment are fitted with electric lights encased in waterproof and pressure-proof globes which provide illumination of the locks and compartment during escape operations. In addition one large 5,000-watt light with cable of proper length to reach from the loft to the top of the submarine escape compartment at the bottom of the tank is provided for illuminating the bottom of the tank when the men are emerging from the compartment. This light can also be suspended to the level of the side locks and adjacent thereto if desired.

94-96.

The 5,000-watt lights mentioned above are not designed to burn in air. If they are lighted in air, the heat generated melts the filament instantly. They should not be lighted until submerged, and they should be extinguished before they are withdrawn from the water. The bell is considered to serve a useful purpose in its availability for descents to investigate any apparent difficulty being experienced by the trainees in their ascent and to rescue them in the event of casualty.

94-97.

(1) While it is not possible to simulate the conditions of actual escape as closely with diving bells as with the specially designed training tanks, bells of the type shown in Fig. 94-9 can be satisfactorily used for familiarizing personnel with the use and operation of the "Lung" under open-sea conditions. They can also be satisfactorily used for repeat training and are approved for this purpose in cases where training tanks are not available, provided that such training is supervised by competent training and medical personnel and that a recompression chamber is available for emergencies.

(2) The bell (Fig. 94-9) is large enough to hold five or six persons. Oxygen for inflating the "Lungs" was obtained from a large oxygen flask secured in the bell. The top of the bell was provided with a hose connection and air hose by means of which compressed air could be supplied from the surface at sufficient pressure to keep down the water level in the bell.

94-98.

(1) In any underwater work, such as is involved in diving or in making ascents from any depths with a respiratory apparatus, such as a diving suit and the "Lung", the users of such devices are subject to abnormal conditions, which, under certain circumstances, have long been recognized to be hazardous,

and proper precautions are necessary to offset their detrimental effects.

(2) When compressed normal air (consisting of approximately 20 percent oxygen and 80 percent nitrogen) is breathed, the nitrogen is taken up in solution by the blood and tissues of the body. When the pressure is released, the nitrogen is released by the tissues and blood in a gaseous state. If the release is sudden, the large bubbles formed collect around the lesions and muscles and cause what is commonly known as bends.

(3) To prevent contraction of these symptoms, it

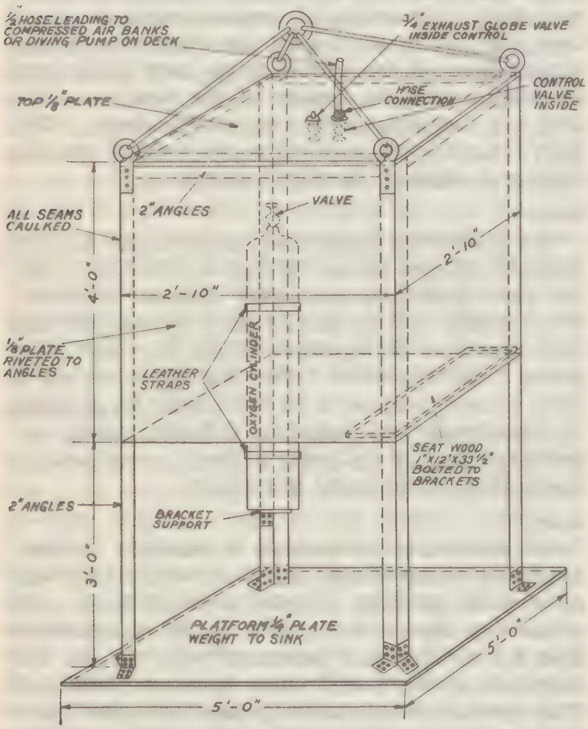

FIGURE 94–9.

is necessary that the release of pressure beyond a certain stage be gradual. In diving work this is accomplished by requiring the diver, after he has ascended a certain proportion of the distance to the surface, to stop at various stages for certain periods throughout the remainder of the ascent for proper desaturation.

94–99.

When breathing under pressure, the air in the lungs is at the same pressure per square inch as the pressure of the surrounding medium. Upon release of pressure, such as occurs on ascents in water, the air in the lungs expands, and if it cannot be exhausted as rapidly as it expands, the internal pressures developed in the body exceed the decreasing pressures of the surrounding medium. The maximum internal excess pressure which the average man can withstand is about three pounds per square inch. In free ascents in water, without apparatus or ascending lines to regulate the ascent, the buoyancy of the average man is such that his rate of rise will be approximately 2½ feet per second. This is too rapid to permit the exhaust of air from his lungs in ratio with the surrounding decreasing pressures and the internal air rapidly builds up to a dangerous pressure. The same condition obtains if the subject holds his breath during ascent. A tendency to do this on the part of some trainees has been noted, probably due to the practice developed in swimming and diving. The fact that after breathing pure oxygen the breath may be held a much longer time than after breathing air may also contribute to this tendency.

94–100.

(1) Extensive experiments conducted by the Bureau of Medicine and Surgery have conclusively determined that air embolism is produced when the intrapulmonic pressure is suddenly raised and abruptly released. For instance, air bubbles appeared in the carotid artery of an anesthetized dog within two or three seconds on suddenly releasing a pressure of 1.5 pounds per square inch which had been set up in the lungs. On autopsy, air bubbles were formed in the cerebral and coronary vessels, in the heart and other organs, the amount and distribution of the bubbles depending on the degree of intrapulmonic pressure which had been induced. Numerous small haemorrhagic areas were observed in the lungs.

(2) In ordinary diving work, the possibility of air embolism in the diver is remote, as the diver is always hoisted to the surface at a proper rate by tenders on deck of the surface ship. In individual escape from submarines, however, and "Lung" training the possibility is more pronounced. It could and probably would occur (1) through a too-rapid ascent, (2) by the subject, through fear or other causes, holding his breath during ascent, and (3) by defective apparatus interfering with adequate breathing.

94–101. PRECAUTION FOR "LUNG" TRAINING

The prevention of contraction of "bends" and the prevention of development of air embolism in the body lie in the physical fitness of the man; the satisfactory functioning of the escape apparatus; proper decompression and a gradual release of the intrapulmonic pressure in the body. Proper decompression and gradual release of the intrapulmonic pressure are the main objectives, and they can be attained by well-regulated ascents. Therefore, the following precautions should govern all training work with "Lung":

1. All candidates for training shall be physically qualified in accordance with Bureau of Medicine and Surgery requirements. See article 94–107.

2. All candidates shall thoroughly understand the principle of operation of the "Lung," and the function of each of its constituent parts before being permitted to wear it submerged.

3. No candidate for submarine training shall be permitted to use the "Lung" until the instructor in charge has examined it and found that it functions satisfactorily and, in particular, that the following constituent parts are properly assembled in the "Lung" and in good condition:

(*a*) That the rubber mouthpiece contains both rubber lugs and that all parts are in good condition.

(*b*) That the mica disc valves in the metal housing, which govern the directional flow of inhalations and exhalations, are in satisfactory working order. This will be evidenced by a pronounced clicking of the valves when inhaling and exhaling.

(*c*) That filling plug and sealing cap of the canister are secured watertight.

(*d*) That the canister wire mesh internal screens are not clogged with soda lime or water.

(*e*) That the rubber relief valve is intact and functions satisfactorily in releasing excess air in the bag with the bag submerged with the top awash.

(4) Training should be given only by personnel who have been trained and have qualified in the use of the "Lung," preferably by those who have received this training either at the submarine base, New London, Connecticut, or the submarine base, Pearl Harbor. It is considered that an officer who is thoroughly familiar with the use of the "Lung" and training procedure should always be present when training with the "Lung"; that when escape training is under way, the officer in charge of training or a qualified chief petty officer detailed by the officer in charge and also a medical officer should be at the top of the tank or point of emergence from the water, and an officer or qualified chief petty officer should be in the lock or submarine compartment from which escape is made; and that a medical officer should be in attendance when the recompression chamber is being used.

(5) The instructors in charge of the training should take every precaution to insure that the candidate properly inhales from and exhales into the "Lung" before permitting his submergence and ascent. This should be accomplished by the candidate submerging just below the surface of the water under the strict observance of the instructor, who should see that the candidate is properly using the "Lung"; that the breathing bag is properly inflated with oxygen; that the nose clip properly seals the nostrils; that the mouthpiece is properly gripped by the teeth; and that he is breathing slowly and deeply. Candidates should not be permitted to descend to depths in excess of 7 feet (measured from the surface to their feet) with a "Lung" which has been inflated at the surface (the head should not descend more than about 1 foot below the surface). In all cases of escape the instructor should have each man put on his "Lung" just before leaving the lock, compartment, or bell and take a few breaths, this for a final check as to whether the apparatus is functioning properly and the mouthpiece valve is open. Also any soda lime dust that is drawn through the mouthpiece may be expelled from the mouth and lungs before the man is in the water.

(6) *Practice ascents up to 12 feet.* In practice ascents, the first ascent should be from a depth not greater than twelve (12) feet from the surface of the water to the man's feet, and before completion of training at this depth, the man under instruction should be required to make at least one stop between the twelve-foot depth and the surface, for a period of about 30 breaths or two minutes, to insure his proper breathing into the "Lung." All necessary precautions to insure this proper breathing should be taken, and, if necessary, the man under instruction should be accompanied by his instructor. Men should be cautioned against the tendency to let go of the line after taking the 30 breaths. They should be instructed how to leave the bell—reach outside and grasp the line with the right hand, place the left hand against the inside of the bell, duck under the skirt, turn and face the line, then slide up until the feet can be placed one on either side of the line. The body should be fairly erect, the two hands grasping the line at about the waist level. The pressure exerted on the line by the hands and knees should be such as to permit the line to slide between them about as slowly as possible which will be at about the rate of 50 feet per minute. Men should follow the same procedure in putting on the "Lung" as they did when training on the ladders. They should form the habit of breathing oxygen for two or three minutes before leaving the bell or lock, both for the assurance that everything is all right and for the greater decompressing effect. Men should be cautioned that if the bag is accidentally squeezed on leaving the bell, they should return, if possible; otherwise continue slowly the ascent to the surface, exhaling and inhaling normally. The action of ascending will automatically inflate the bag. They should understand that the escape of air from the relief valve is not only harmless but necessary, and that especially on ascents from greater depths, air will and must escape from the flutter valve on each exhalation. Men should be instructed that if anything unusual happens, such as losing the mouthpiece out of the mouth, the ascent can be made from this depth without a "Lung" provided the expanding air in the man's own lungs is released by exhalation. If the buoy line is lost, the man should attempt to retard his rate of ascent by any means possible and exhale forcibly. At least two satisfactory practice ascents at this depth should be made before the candidate is considered qualified and ready to undertake the regular training ascents from the 18-foot depth.

(7) *Qualifying ascents from 18-foot depths.* There shall be at least three ascents made from the 18-foot depth before the trainee is considered as qualified. The ascents from this depth are mandatory. The first ascent shall be made with a stop for decompres-

sion in accordance with the following decompression table. The subsequent ascents shall be made without stops at a speed of about 50 feet per minute. Careful training and instruction as to the rate of ascent should be given in order that the speed of about 50 feet per minute may be adhered to.

(8) *Volunteer qualifying ascents from 50-foot and 100-foot depths.* (*a*) Ascents from 50-foot depths and 100-foot depths shall be voluntary and limited to trainees who have just previously qualified in ascents from the 18-foot depth. There should be at least two ascents from the 50-foot and 100-foot depths. The first ascent from each of these depths should be with stops for decompression in accordance with the following decompression table. The other ascent should be without stops at a speed of about 50 feet per minute. Preferably for the same individual there should be at least 1 day's lapse of time between the ascent made from the 50-foot lock with decompression stops and his ascent from this depth with the uniform ascent method. In no case should the interval between these two ascents from this depth be less than 4 hours. In making the two ascents from the 100-foot depth the interval of time between the first ascent and the second ascent should not be less than a day nor more than three days. Ascents from the 100-foot depth shall not be made until the trainee has qualified in ascents (with stops for decompression and without stops at a uniform rate of 50 feet per minute) from the 50-foot depth. Continuation of a trainee's qualification in ascent from either of these depths, using the uniform rate of ascent without stops, shall be at the discretion of the supervising officer.

Decompression table

Ascent from depth in feet	Stops in feet from surface				
	50	40	30	20	10
100	10	10	10	10	10
75 [1]		10	10	10	10
50				10	10
30 [1]					10
18					10

[1] Thirty (30) foot and seventy-five (75) foot ascents have been listed in the above table with the view that the officer in charge of training may consider it necessary to have ascents from intermediate depths for some trainees.

(*b*) The time of stops given above are in the number of breaths to be taken; ten breaths should be taken at each stop. The man under instruction should in all cases be warned that if, for any reason, it is found impossible to make these decompression stops, then, as an alternative, a uniform ascent should be made at a rate not exceeding 50 feet per minute. Similarly, if the buoy is lost, the man should attempt to retard his ascent by using his hands to "back water" and he should endeavor to exhale forcibly.

(9) Before using "Lungs" they should, in all cases, be closely examined to see that the soda lime within the canister has not become damp and clogged, and that the wire mesh strainers are clear of soda lime and moisture. The same soda lime within the "Lung", even if dry, should not be used for more than 12 ascents.

(10) Renewal of the soda lime should be with the special type of hard soda lime which the Bureau has prescribed for this purpose.

(11) In all ascents the "Lung" should be inflated with oxygen until it escapes via the relief or flutter valve with the top of the bag awash. In no case should the men under training be permitted to inflate the "Lung" initially with their own breath.

(12) Breathing through the "Lung" should be begun from 2 to 3 minutes before beginning ascent; such period should not, however, be greater than 3 minutes. In order that the concentration of oxygen should be as high as practicable so as to accelerate decompression to the maximum, the breath should be forcibly and completely exhaled through the nose immediately before taking in the first breath of oxygen from the "Lung". The nose clips should then be applied immediately and complete breathing thereafter made through the "Lung" direct.

(13) In inflating the "Lung" care shall taken that the bag is inflated, and that the mouthpiece is inserted in the mouth before the valve in the mouthpiece is fully opened.

(14) The rubber mouthpiece of the "Lung" should be disinfected after use by each trainee.

94–102. TREATMENT FOR CAISSON DISEASE AND AIR EMBOLISM

The treatment for caisson disease and effects of air embolism is immediate recompression and decompression. The patient should be immediately transferred to a recompression chamber. The instructions contained in the diving manual relative to caisson disease should govern the management of the patient in relation to the recompression chamber. If the symptoms are caisson disease, the maximum pressure to which the patient should be recompressed, the time of exposure at this pressure, and the schedule of his decompression must be left to the judgment of the attending medical officer. If the patient is suffering from air embolism, the pressure in the chamber should be rapidly raised to at least 45 pounds per square inch. There is no contraindication to higher pressure, if deemed necessary. The time of exposure to this pressure and the rate at which it is subsequently lowered must be left to the discretion of the attending medical officer. Other symptomatic measures such as cardiac stimulation with adrenalin and artificial respiration should also be considered.

94–103.

Training with the submarine escape apparatus should not be conducted unless a recompression chamber is immediately available for treatment.

94–104. REPEAT TRAINING

Proficiency in use of the "Lung" and the natural fear which submergence induces in some personnel

can be overcome only by continued ascents. The benefit which occurs to trainees from their original qualification will probably not have any substantial degree of permanency without repeat training. While training in submarine escape is a function of the Fleet, the Bureau of Ships advocates that repeat qualification annually or as near annually as practicable in ascents with the "Lung" be enforced as a qualification for continued submarine duty.

94–105. QUALIFICATION FOR REPEAT TRAINING

(1) Men who have had previous "Lung" training up to the 18-foot escape requirement will be required to take only the following:

(*a*) Physical examination.

(*b*) Pressure up to 25 p.s.i. (absolute) in the recompression chamber.

(*c*) Practice breathing in the "Lung" on the ladders.

(*d*) One 12-foot escape with one stop for 30 breaths.

(*e*) One 18-foot ascent at the rate of 50 feet per minute.

(2) If these men on repeat training desire and volunteer for training from the greater depths, they shall be required to qualify in the recompression chamber in accordance with the requirement for initial qualification. After so qualifying, the training from the 50-foot lock may be given on the same day after an interval of 4 hours and after reexamination physically. Voluntary training from the 100-foot depth may be given at any time within 3 days after training from the 50-foot lock is completed. In no case shall a man be qualified in the recompression chamber and trained in escape from the 50-foot lock and the 100-foot compartment all in one day.

94–106.

Men who have previously completed the entire course including the 50-foot and 100-foot escapes will on repeat training be subjected to the same preliminary qualification as specified above for those whose previous training did not include escapes from the greater depths, provided the repeat training is limited to escape from the 18-foot depth. If repeat training is volunteered for the greater depths, they shall first be subjected to the physical and compression requirements governing their acceptance for their qualification. If accepted, they shall make one continuous ascent from the 50-foot lock after the requalifying ascent from the 18-foot lock and one continuous ascent from the 100-foot compartment after requalifying in the 50-foot ascent. The interim between ascents should be the same as prescribed above for persons whose previous qualification did not include ascents from these greater depths.

94–107. PHYSICAL REQUIREMENTS OF CANDIDATES FOR "LUNG" TRAINING

Every candidate for submarine escape training with the "Lung" should be subjected to preliminary physical examination. The physical requirements governing the acceptance of candidates have been promulgated by the Bureau of Medicine and Surgery. They are quoted for information as follows:

(1) General requirements for submarine duty as laid down in paragraph 1534 of the Manual of the Medical Department.

(2) *Ears.*—The capacity to withstand an air pressure of 50 in a recompression chamber. It should be remembered, however, that there may be temporary difficulty due to acute congestion of the Eustachian tube as a result of coryza.

(3) *Teeth.*—Trainees with upper or lower dentures to be excluded as it will be impossible to hold the mouthpiece of the apparatus properly in position.

Trainees with absence of teeth in such location as to interfere with the proper gripping of the mouthpiece are also to be excluded.

(4) *Respiratory system.*—In addition to the usual examination, trainees should be especially cautioned against breath holding during ascent.

(5) *Cardio-vascular system.*—The pulse and blood pressure are to be taken before, immediately after, and 3 minutes following exercise which shall consist of 20 standing hops on each foot not faster than one (1) hop per second. Trainees showing definitely subnormal circulatory efficiency are to be excluded.

(6) *Abnormal psycho.*—The question as to whether a candidate is qualified to take the training because of nervous instability or apprehension is to be carefully considered.

(7) *Health record.*—An entry will be made in the health record to the effect as to whether or not physically qualified for training; any defects found being also entered. The medical history will be carefully considered.

Part 6. Rescue Chamber

94–121. IDENTIFICATION

Submarine rescue chambers are assigned to submarine rescue vessels (ASR) as part of their equipment. From 1932 to 1943, rescue chambers were classified as district craft with the identification symbol "YRC" followed by a serial number. This classification and the use of the symbol YRC has been discontinued. Rescue chambers are identified by serial number, beginning with serial No. 1 for the rescue chamber formerly designated as YRC–1.

94–122. SUBMERGENCE DEPTH

The rated operating depth and test depth are shown below for each design. Chambers of the same design are grouped together. Each group represents a different design.

Rescue chamber serial number	Rated depth	Test depth (no personnel aboard)
	Feet	*Feet*
(a) 1 to 5	300	400
(b) 1A, 6, 7	400	600
(c) 8 to 19	550	750

94–123. DESCRIPTION

(1) The submarine rescue chamber is a steel structure about 11 feet high having a weight of approximately 18,000 pounds and a maximum outside diameter near the top of 94 inches (Nos. 1 to 7 and 1A) or 84 inches (Nos. 8 to 19) tapering to a diameter of 60 inches at the bottom. It is open at the bottom and around the bottom edge is a rubber gasket. The chamber has three divisions; the upper compartment, the lower compartment, and the ballast tank. Chambers Nos. 1 to 7 and 1A are shown on figure 94–10 and Chambers Nos. 8 to 19 are shown on figure 94–11. A plan view of the rescue chamber is shown on figure 94–12.

(2) On the outside and top of the chamber are four watertight fittings for air supply, venting from the interior, the telephone wire, and the electric light cable. The connections go directly into the upper compartment. Air is supplied from the tending vessel through a 1-inch wire-wound hose. Air is vented through a 1¼-inch wire-wound hose which also runs to the surface vessel. The telephone and electric light cables are standard rubber insulated copper wires.

(3) A hatch with a raised coaming about it permits entrance from the top to the upper compartment. A drain valve which can be operated from the top or from the upper compartment allows the escape of water from the hatch coaming.

94–124. UPPER COMPARTMENT

(1) The upper compartment comprises the upper portion of the rescue chamber and contains all the operating gear except the reel for the downhaul wire. It is the compartment in which the operators and passengers ride.

In the upper compartment are—

(*a*) The operating motor with air supply and exhaust lines and valves.

(*b*) The upper compartment blow valve.

(*c*) The upper compartment vent valve.

(*d*) The blow and vent manifold for the power compartment and ballast tank.

(*e*) The water manifold for flooding and emptying the lower compartment and ballast tank with a hose connection and valve for filling the portable adjusting tanks.

(*f*) Portable adjusting tanks.

(*g*) One caisson gage.

(*h*) One sea pressure gage.

(*i*) The lighting system.

(*j*) The telephone to the surface ship.

(*k*) Two portable battery lamps.

(*l*) Four holding down rods.

(*m*) The access hatch to the top of the chamber.

(*n*) The access hatch to the lower compartment.

(*o*) Hydraulic hand pump for operating downhaul cable cutter (Chambers Nos. 1A and 6 to 19).

(2) The operating motor is air-driven. It is geared to a reel located in the lower compartment on which is wound the wire for raising and lowering the chamber. The controller is on the air-supply line and by the movement of the controller the direction of the motor's rotation is determined. When the controller is moved to its limit by a downward movement of the wrist, the motor operates to reel in the cable. When it is moved to its limit by an upward movement of the wrist, the motor slacks out the wire. A clutch and brake are fitted for use when it is desirable to

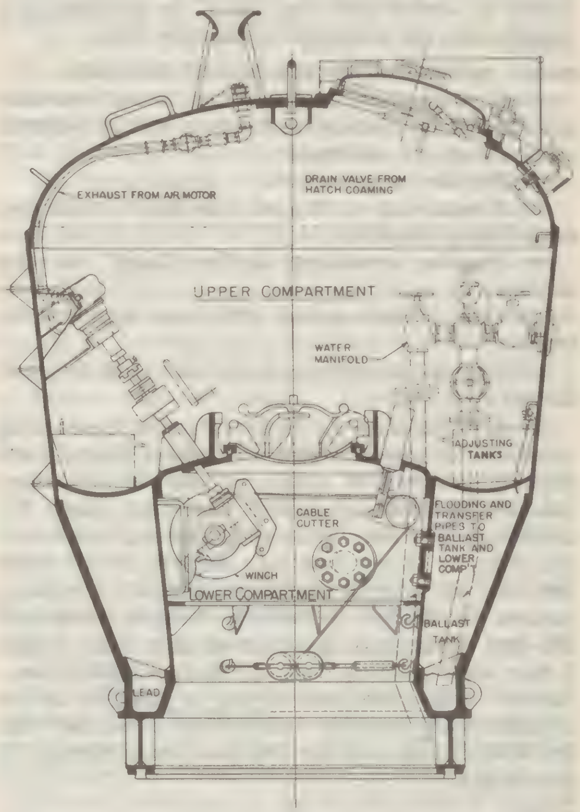

FIGURE 94–10.

slack the wire faster than the motor can run. The motor is designed so as to stall before submitting any part of the system to a breaking strain, and so may be operated at full speed without danger of parting the wire cable. Rescue chambers Nos. 1A, and 6 to 19 are provided with hand gear for use in raising or seating the chamber by hand power should the motor fail.

(3) *Air Supply*. The motor takes its air supply through the control valve overhead directly from the air-supply line from the surface connection. It exhausts through the exhaust valve, also overhead, directly into the vent line which runs to the connection on the top of the chamber.

(4) *Clutch*. The clutch of the motor is engaged and disengaged by lowering and raising the upper clutch disc. A hand-operated brake encircles the shaft below the clutch.

(5) *Blow Valve*. The upper compartment blow valve is overhead on the air-supply line, and the vent is in a similar position on the vent line.

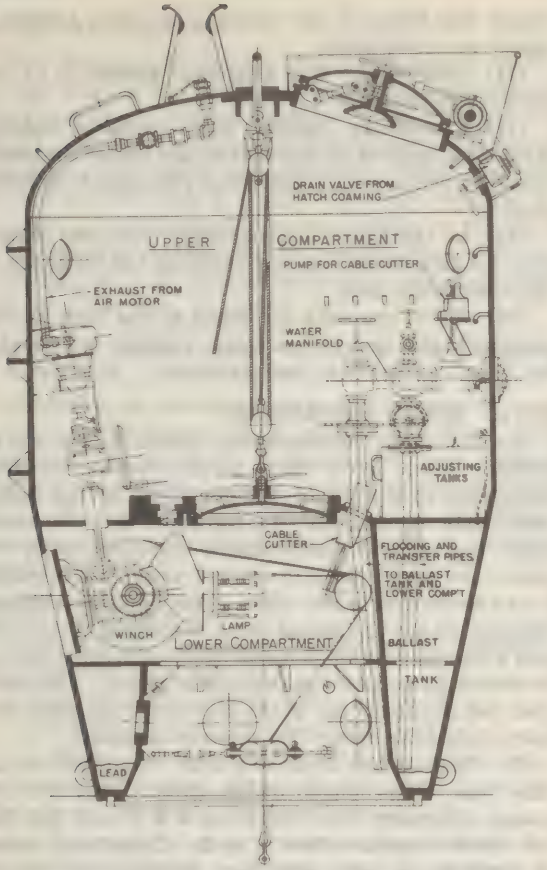

FIGURE 94–11.

(6) *Blow and Vent Manifold.* The air-supply line terminates at the blow and vent manifold just to the left of the motor. At this manifold is the lower compartment blow valve and the ballast tank blow valve, which when opened admit air to the top of their respective compartments. On the blow lines from the valves to the lower compartment and to the ballast tank are the lower compartment and ballast tank vent valves. Both the lower compartment and the ballast tank vent into the upper compartment and the air from there escapes to the surface through the upper compartment vent valve. Three additional ballast tank vents (see fig. 94–13) are provided for rescue chambers Nos. 1A and 6 to 19. These vents are located at intervals around the chamber and consist of a short length of 1-inch pipe leading from the top of the ballast tank to a valve in the upper compartment.

(7) *Water Manifold.* Just to the left of the blow and vent manifold is the water manifold. This consists of the sea valve, the lower compartment flood valve, the ballast tank flood valve, and the valve for the hose connection. With the sea valve open, sea water flows through an opening in the hull and through a line to the two flood valves and hose valve. From the flood valve, flood lines run to the bottom of their respective compartments. On both

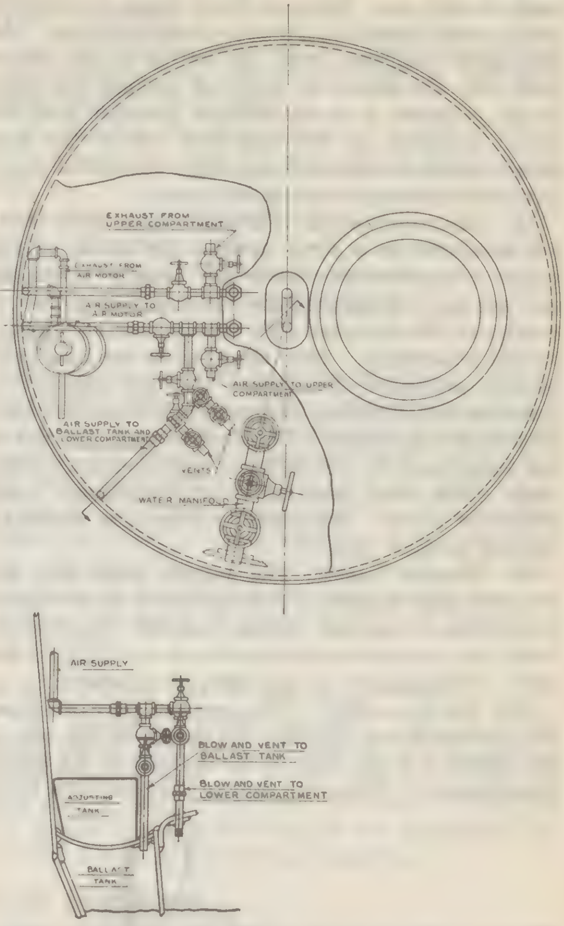

FIGURE 94–12.—Rescue chamber. Typical plan view and sectional view of blow and vent manifold.

the air and water manifolds the inboard valves go to the lower compartment and the outboard ones to the ballast tank.

In addition to the water manifold, rescue chambers Nos. 1A and 6 to 19 are fitted with three 1-inch spill pipes (see fig. 94–14) which connect the ballast

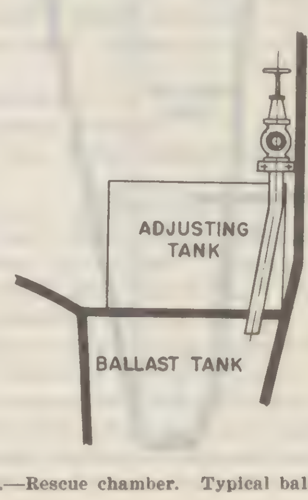

FIGURE 94–13.—Rescue chamber. Typical ballast tank vent.

tank to the sea. Each of these pipes is provided with a valve located in the upper compartment. The spill pipes terminate near the bottom of the ballast tank and are spaced at intervals around the tank. If the chamber is in an inclined position with the water manifold on the high side, use of the spill pipes instead of the water manifold will permit more complete blowing of the ballast tank.

(8) *Adjusting tanks.* Portable galvanized tanks are arranged in a circle around the inside of the upper compartment. They are readily accessible and are used to compensate for the gain or loss in weight of the chamber with the entrance or departure of passengers. They are filled by the hose connection previously mentioned and are emptied by dumping into the lower compartment when the connection hatch is open. The number and capacity of the tanks vary for the different rescue chamber designs. The total capacity is approximately 1,000 pounds of water. The capacity in pounds should be painted on each tank.

(9) *Pressure gages.* The caisson gage and sea pressure gage indicate the air pressure in the upper compartment and sea pressure outside respectively. They are located on the inside of the hull in the upper compartment to the right of the motor.

(10) *Electric cables.* The electric light cable from the surface passes through the fitting on the top of the chamber to the wire in the interior of the upper compartment. This wire runs to the switchbox from which the lights in the upper and lower compartments are controlled.

(11) *Telephone.* The telephone system is of the batteryless type.

(12) *Emergency lights.* Two portable battery lamps are secured to the hull in the upper compartment for use in case of failure of the regular lighting system.

(13) In the upper compartment are also stowed four holding down rods for securing the chamber to the submarine hull.

(14) Three eyeports are fitted in the hull in this compartment and at least one eyeport is provided for viewing the lower compartment.

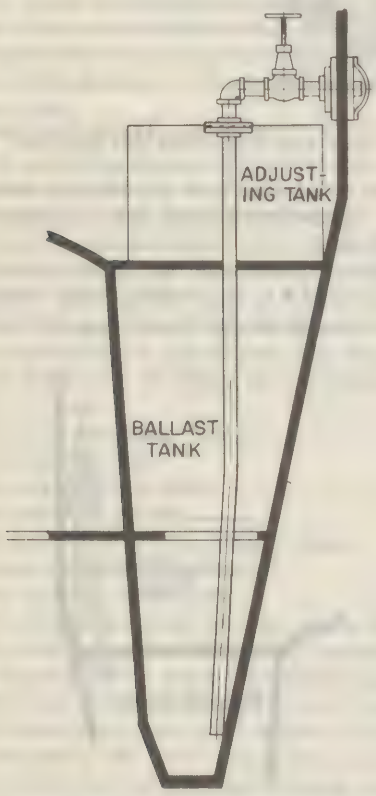

FIGURE 94–14.—Rescue chamber. Typical spill pipe.

94–125. LOWER COMPARTMENT

(1) The lower compartment, which is open at the bottom, is the lower space in the rescue chamber, connected to the upper compartment by the hatch previously mentioned. It contains the downhaul cable and reel, a snatch-block through which the wire runs, and a fairlead for the wire which centers it in the compartment when hauling in or veering. One end of the downhaul cable is secured to the reel and a special shackle is made fast to the other end to fit the hatch bale on the submarine hatch. The fairlead can be moved out of the way after the cable has been unfastened from the submarine hatch.

(2) The downhaul cable is 7/16″ diameter, 6 x 37 wire rope. The length of the cable is 400 feet for rescue chambers Nos. 1 to 5, 1A, 6 & 7, and 850 feet for rescue chambers Nos. 8 to 20. Downhaul cables of high grade plow steel are provided for rescue chambers prior to No. 8. Rescue chambers Nos. 8 to 19 have a spooling mechanism which is designed with closed tolerances for use with CRS wire rope. The type of spooling device may not perform satisfactorily with plow steel rope particularly if sufficient corrosion exists to produce variation in the rope diameter.

(3) The blowing, venting, and flooding connections in the lower compartment are all controlled from the upper compartment (see article 94–124).

(4) In a circular web running around the inside of the hull in the lower compartment are a number of slots spaced at equal intervals. The holding down rods, stowed in the upper compartment, fit into these slots and the nuts are screwed tight against the web. The shackle on the bottom of the rod is secured to a pad eye outside the submarine hatch, and with four rods in use, the chamber is held tightly to the hull of the submarine. The occasion for the use of these rods and details of securing them will be described later.

(5) Rescue chambers Nos. 1A and 6 to 19 are provided with a cable cutter for emergency use. This device is permanently mounted in the lower compartment in way of the downhaul cable and is operated from the upper compartment by means of a small hydraulic hand pump.

(6) The lower compartment has a capacity of about 3,000 pounds of salt water.

94-126. BALLAST TANK

The ballast tank is a closed annular compartment in the hull of the rescue chamber and surrounds the lower compartment. Access to the ballast tank may be had through the handholes, closed by bolted plates, in the lower compartment. The capacity of the ballast tank is almost the same as that of the lower compartment. In the bottom of the tank is placed lead ballast for regulating the weight of the chamber. Air and sea connections are described in article 94-124.

94-127. FLOODING AND BLOWING OF RESCUE CHAMBER

Inasmuch as the fitting out and testing, as well as the actual rescue work, entails the filling and emptying of the lower compartment and ballast tank, a description of each operation will be given here. It is assumed the chamber is in the water with all hose connections attached and all hatches and valves closed.

94-128. FLOODING

(1) To flood the lower compartment (chamber not attached to submarine):

(*a*) Open upper compartment vent valve.

(*b*) Open lower compartment vent valve.

(*c*) When water comes through the lower compartment vent valve, close the valve and open the petcock on the top of the connecting hatch.

(*d*) When water comes through the petcock, the lower compartment is flooded and the petcock is then closed.

(2) To flood the lower compartment (chamber attached to submarine):

(*a*) Open the upper compartment vent valve.

(*b*) Open the lower compartment vent valve.

(*c*) Open the sea valve on the line to the water manifold.

(*d*) Open the flood valve to lower compartment.

(*e*) Proceed as before, closing the sea valve and flood valve when the compartment is full. (This operation requires considerable care to avoid breaking the seal of the chamber to the submarine and the precautions to be taken are described in article 94-154.)

(3) To flood the ballast tank:

(*a*) Open the upper compartment vent valve.

(*b*) Open the ballast tank vent valve.

(*c*) Open the sea valve on the line to the water manifold.

(*d*) Open the flood valve to the ballast tank.

(*e*) When water comes through the ballast tank vent valve, close the valve and continue the venting through three petcocks spaced around the bottom of the upper compartment at intervals of one hundred and twenty degrees. When water comes through petcocks, the tank is full and the petcocks are closed.

(*f*) Close the sea valve and flood valve.

94-129. BLOWING

(1) To blow the lower compartment: Open lower compartment blow valve until bubbles are seen rising outside the chamber.

(2) To blow the ballast tank:

(*a*) Open sea valve on flood line to water manifold.

(*b*) Open ballast tank flood valve.

(*c*) Open ballast tank blow valve until bubbles are seen rising outside the chamber.

(*d*) Close sea valve and flood valve.

94-130.

Should the occasion ever arise when it would be necessary to blow the lower compartment through the water manifold, the operation is exactly the same as for blowing the ballast tank except that the flood valve and blow valve for the lower compartment are opened instead of the corresponding ballast tank valves. This condition may occur when the bottom of the chamber is drawn by the cable too close to the hatch seat of the submarine, preventing the egress of water around the bottom of the chamber.

94-131. FITTING OUT OF RESCUE CHAMBER

The submarine rescue chamber with its accessories under ordinary circumstances will be kept at the submarine base. It is most important that the unit having custody keep the chamber in condition for instant use and see that all the accessories are present and in good working condition.

94-132. EQUIPMENT

The following accessories are provided for each rescue chamber:

Air supply hose, 1 inch inside diameter (BUSHIPS Ad Interim Specification 33H14INT) in 50-foot lengths. Total of 700 feet for rescue chambers Nos. 1 to 5, 1A, 6 and 7, and 950 feet for rescue chambers Nos. 8 to 19.

Air vent hose, 1¼ inches inside diameter (BUSHIPS Ad Interim Specification 33H14INT) in 50-foot lengths. Length same as for air supply hose.

Telephone cable. Length equal to length of air hose.

Two telephones.

One telephone cable reel.

Electric light cable. Length equal to length of air hose.

Wire pendant, ½ inch diameter 6 x 37 high grade plow steel wire rope for towing and for tending the chamber from the surface. Length 700 feet for rescue chambers Nos. 1 to 5, 1A, 6 and 7, and 850 feet for rescue chambers Nos. 8 to 19.

One lifting pendant, 1 inch diameter 6 x 19 high grade plow steel wire rope, 8 feet long.

One bag of tools, consisting of monkey wrenches, Stillson wrenches, pliers, hammer, tape, pinchbar, and such other tools as experience may show the need for.

Four holding down rods with nuts.

Two battery lamps.

Four submarine escape appliances (lungs).

The tools, lamps, rods, and "lungs" should be kept in the chamber.

94-133. BUOYANCY

(1) The rescue chamber should have just enough ballast in the form of lead inside the ballast tank so that it will have a positive buoyancy of 1,000 pounds with the lower compartment full of water, the ballast tank dry, the adjusting tanks full of water, and two operators in the upper compartment. To determine the reserve buoyancy of the chamber proceed as follows:

(*a*) Close all the valves in the chamber and also the hatch between the upper and lower compartments.

(*b*) Place the chamber in the water.

(*c*) Send two men in the upper compartment.

(*d*) Fill all the adjusting tanks with water.

(*e*) Hook the lowering pendant to the hook of the crane, keeping the pendant slack.

(*f*) Flood the lower compartment.

(*g*) Close the upper hatch.

(*h*) Place weights or men on the top of the chamber until it is completely under water.

(2) The amount of weight necessary to submerge the chamber completely is the reserve buoyancy under these conditions. It should be made 1,000 pounds by adding or removing lead ballast in the ballast tank.

94-134. TOWING

(1) It has been determined that the most practicable method of taking the rescue chamber to the scene of operations is by towing. Its great weight and the danger of rough handling in a seaway render the carrying of it aboard the rescue vessel inconvenient and at times dangerous. The gasket on the bottom is especially liable to injury in handling the chamber on a ship.

(2) For towing, the chamber is placed in the water with all loose articles well secured, all valves and hatches closed, and the ballast tank dry. A towing wire is run from the stern of the vessel to the lifting pendant of the chamber and towing is done astern. Towing may be done at any speed the wire can stand. At speeds of more than 5 knots the chamber will not tow upright but the only effect of this will be to flood the lower compartment partly. The chamber cannot sink under these conditions if it is properly ballasted, the ballast tank is dry, and there are no leaks. Obviously the interior must be well secured and the hatches screwed down tightly.

(3) Before starting the tow, the downhaul cable should be run about 20 feet, and the shackle end pulled outside the chamber and secured to the top of it for ready access to the diver.

94-135. RESCUE OPERATIONS

(1) Upon arrival over the sunken submarine, the rescue vessel lays out a mooring with the center as nearly as possible over the submarine. During the laying of the moorings, the chamber may be given to another vessel or may be held by one of the ship's boats. The rescue vessel then hauls herself to such a position that the submarine lies to leeward about 50 to 100 feet. The chamber is brought to the lee side of the rescue vessel and all connections are made.

(2) The 1-inch hose is connected to the ship's compressor or air banks and to the fitting on the rescue chamber. The 1¼-inch hose is secured with one end on board the rescue vessel open to the atmosphere and the other end secured to the proper fitting on the chamber. The telephone cable is secured to the chamber fitting; the chamber telephone is plugged in; the other set is connected to the telephone cable on the deck of the rescue vessel. The light cable is plugged into the ship's circuit and the other end is secured to the proper fitting on the chamber. All connections, telephone, lights, air, and vents, are tested out. An air pressure at least 50 p. s. i. greater than the water pressure at the depth at which the submarine lies should be kept in the air supply line. Once the connections are made, the chamber can be kept fended off until ready for the descent.

(3) While this work is going on, the diver is preparing for his descent and should go down as soon as everything is ready. After arriving on the submarine's deck, he first clears away any material which may block the approach to the hatch, and makes sure that nothing lies on or in the vicinity of the seat surrounding the hatch. The shackle end of the rescue chamber downhaul cable is then made fast to the bale on the submarine hatch. The diver is then brought to the surface and stands by for a descent if his services are needed by the crew of the rescue chamber.

94-136. DESCENT

(1) The chamber is now ready for the descent. Two operators are sent inside and the upper hatch is closed again. In case more than two men are sent down in the chamber, sufficient water ballast must be left out of the adjusting tanks to compensate for the weight of the number in excess. Roughly, leaving two cans empty will take care of the weight of one man. If only the two men are in the chamber, all the tanks should now be filled using the hose on the water manifold.

(2) As the chamber descends, the hose, telephone wire, and light cable are bound together for convenience in handling and paid out. The wire attached to the lifting pendant is also paid out. There is never a strain on this wire and it is necessary only to pull the chamber over to the rescue vessel after the ascent. The steps taken in making the descent are now given in order:

(*a*) Make sure the ballast tank is empty by blowing it until bubbles rise outside the chamber. Then secure the ballast tank and vent the excess pressure in it by opening the ballast tank vent and upper com-

partment vent. After it is vented, close the ballast tank vent leaving the upper compartment vent open.

(*b*) Flood the lower compartment. After it is flooded, close the upper compartment vent.

(*c*) Turn on the light in the lower compartment. Place the motor controller in the down position and open the motor air supply valve. The controller should be kept in this position and the motor regulated by the valve.

(*d*) Open the motor exhaust valve.

(*e*) The motor will now begin to reel in the cable drawing the chamber down toward the submarine. Watch the reel and cable through the eyeport to see that both are running clear.

(*f*) When the bottom of the chamber strikes the submarine hatch seat or, if the visibility is such that the hatch can be seen through the eyeport when the hatch comes into sight, slow down the motor and draw the chamber as tightly as possible against the seat. Should the light reveal obstructions, or the stalling of the motor before the destination is reached indicate that the chamber is caught on some object above the hatch, it will be necessary for the diver to clear it.

(3) When the submarine is listed to one side on the bottom, it may require some maneuvering to get the chamber against the seat and especially to get it reasonably well centered over the hatch. However, it is not impossible at any angle at which the submarine is likely to lie.

94-137. SEATING CHAMBER

(1) To seat the chamber proceed as follows:

(*a*) After getting the chamber as close to the seat as possible, secure the motor with the controller still in the down position. Keep the motor exhaust valve open. Flood the ballast tank. (This is the only occasion when it is permissible to have the lower compartment and ballast tank full simultaneously. The negative buoyancy can do no harm here as the chamber cannot sink further.)

(*b*) Take in any slack gained in the cable by opening the air supply valve frequently during the flooding.

(*c*) Blow the lower compartment, either through the bottom or through the water manifold. Secure the lower compartment.

(*d*) Open the motor air supply valve, open the upper compartment vent, and throw the lower compartment vent wide open. As the lower compartment vents, the sea pressure will seal the chamber tight against the seat, the motor assisting by taking in any slack in the cable as it comes. During the venting the operators may determine if the seal is made by looking through the eyeport into the lower compartment. If the seal is made, the lower compartment will fill with vapor. If the compartment fills with water instead of vapor, the attempt has been unsuccessful and it will be necessary to secure, blow the lower compartment, and try again. Repeated failures indicate an obstruction on the seat which must be removed, either by the diver or, if the operators are experienced, by the chamber crew itself.

(2) To clear an obstruction:

(*a*) Blow out the lower compartment.

(*b*) Raise the chamber about 1 foot from the hatch seat.

(*c*) Secure all valves in the chamber.

(*d*) Open the upper compartment blow valve and build up a pressure in the compartment equal to the sea pressure outside. Then secure the blow valve.

(*e*) Open the lower compartment vent valve and allow the pressure in the two compartments to equalize.

(*f*) Open the lower compartment hatch.

(*g*) One operator descends into the lower compartment and pushes the obstruction clear and then returns to the upper compartment.

(*h*) Close the lower hatch and lower compartment vent.

(*i*) Reduce the pressure in the upper compartment by opening the upper compartment vent, using proper decompression if the pressure has been over 20 pounds.

(*j*) Draw the chamber against the hatch seat and vent the lower compartment as before described to make the seal.

(*k*) When the chamber has been seated against the hatch seat by sea pressure, open the lower latch. The upper compartment vent should remain open.

(*l*) One man descends into the lower compartment-ment and shackles the bottom of each holding down rod to a pad eye in the deck around the hatch. These pad eyes, four in number, are spaced at equal intervals around the hatch. Then the top of each rod is placed in a slot in the web in the lower compartment directly over each pad eye. There are so many slots in the web that one will be at least approximately above each pad eye. The nuts on the rods are screwed down tightly.

Part 7. Conditions in Submarines That May Affect Rescue

94-151.

(1) Before the crew of the rescue chamber open the submarine hatch, they must be prepared for many conditions inside. Only a few of these conditions will be mentioned; each occasion means different conditions and the judgment of the operators must dictate their actions under the various emergencies.

(2) If the submarine compartment is punctured, sea pressure will exist inside with the men breathing in the air space above the water. This condition will make itself apparent to the chamber crew by air escaping around the edge of the hatch as the latter is cracked. Under these circumstances, the hatch is closed again, a pressure equal to the sea pressure outside is built up in the chamber, and the hatch is then opened. After the passengers are removed, taken into the chamber, and the sub-

marine hatch closed, the pressure must be vented through the upper compartment vent before the chamber is unsealed from the submarine. Proper decompression must be used in the venting.

(3) When a submarine compartment contains chlorine gas or carbon dioxide, it is necessary for the crew to use "Lungs" as respirators.

(4) Some confusion may prevail below on account of lack of lights, etc. The handling of this must depend upon the circumstances, as must the almost innumerable other emergency conditions.

94–152. NUMBER OF PASSENGERS TO BE CARRIED

(1) A total of six average-sized men may be taken aboard the chamber without reducing the reserve buoyancy below 1,000 pounds by emptying all the adjusting tanks in the upper compartment. If it is deemed necessary or advisable to carry more, no cans should be dumped, but the chamber should proceed to the surface with the lower compartment empty. Under the latter condition, as many men as the chamber will hold may be taken up.

(2) In considering the number of passengers to be carried, it should be remembered that once a trip has been made, the chamber can make another very quickly, and it is easier to control the chamber with its normal reserve buoyancy at 1,000 pounds than with the much larger buoyancy which will result from the lower compartment being empty even with the upper compartment full of passengers. Furthermore, an excessive number of passengers in the upper compartment may interfere seriously with the work of the chamber crew. Therefore, unless emergency dictates otherwise, the number of passengers taken on the first trip should not exceed six or possibly seven, all the adjusting tanks should be dumped, and the lower compartment filled. In the following description of the ascent, it will be assumed that six passengers are aboard.

94–153. FINAL OPERATIONS BEFORE DETACHING CHAMBER FROM SUBMARINE

The passengers who are to make the trip go to the upper compartment with one member of the chamber crew. The operator in the lower compartment then closes and screws tight the submarine hatch, replaces the fairlead and shackles the down-haul wire to the hatch bale. The other operator then takes in all slack on the wire by running the motor with the controller in the *down position*. When the down-haul wire is taut, the operator in the lower compartment removes the holding-down rods and passes them up into the upper compartment. Then he also enters the upper compartment.

94–154. ASCENT WITH 6 PASSENGERS

The steps in ascent with 6 passengers are as follows:

(1) Empty sufficient number of adjusting tanks into the lower compartment to compensate for the weight of the passengers.

(2) Close the hatch to the lower compartment.

(3) Open the vent from the lower to the upper compartment.

(4) Open the upper compartment vent.

(5) Open the sea valve on the water manifold.

(6) Crack the flood valve from the water manifold to the lower compartment and allow the compartment to flood slowly. The flood valve must not be opened wide, as the vent valve is not sufficiently large to permit the escape of air in enough volume to keep the pressure in the lower compartment atmospheric. If the pressure in the lower compartment equals or approaches that of the sea pressure outside, the seal will be broken prematurely and it is best that the seal be maintained until the chamber is ready to ascend. The progress of the flooding can be observed through the eyeport. When water comes from the lower compartment vent, *close the flood valve* first and then the vent. Then open the petcock in the hatch, crack the flood valve, and continue as before until water comes from the petcock. Then *close the flood valve first* and then the petcock. Leave the sea valve open.

(7) Open the flood valve to the ballast tank. Blow the ballast tank. (During this operation the seal will in all probability remain; if not, no particular harm is done provided the operation is completed quickly.) Secure the ballast tank flood valve and the blow valve when the tank is dry. Leave the sea valve open.

(8) Break the seal by opening the lower compartment flood valve with the lower compartment vent *closed*. The breaking of the seal is noted by the slight swaying or rise of the chamber.

(9) Secure all valves. Place the motor controller in the *up* position and open the motor supply and exhaust valves. The chamber rises as the motor turns, its buoyancy lifting it toward the surface. If it be necessary, disengage the clutch and regulate the speed of ascent by the brake. However, this operation is not advised if it can be avoided.

(10) When the rescue vessel reports by telephone that the chamber is on the surface, blow the lower compartment dry.

94–155. ASCENT WITH MORE THAN 6 PASSENGERS

If more than six passengers are carried, the steps in ascent are:

(1) Close the submarine hatch, shackle up, and take out the holding-down rods as before.

(2) Close the lower compartment hatch.

(3) Blow the ballast tank.

(4) Open the lower compartment blow valve until the seal is broken.

(5) Secure the blow valve and proceed to the surface as before, remembering that the chamber now has a reserve buoyancy at least double the normal buoyancy and that there is a much greater strain on the cable and motor.

(6) After the rescue vessel so directs, open the upper hatch, first draining the space inside the coaming by opening the drawing valve for a few moments and then closing it.

(7) The passengers are sent out and the chamber is ready for another trip.

94–156. ADDITIONAL INSTRUCTIONS ON OPERATION OF RESCUE CHAMBER

(1) When the water is sufficiently deep, and the submarine is on an even keel, and no pressure exists within the vessel, the use of holding down rods may be dispensed with, as the seal caused by sea pressure will be sufficiently strong to hold the chamber tight against the hatch. However, unless haste is important and, in general, in cases of doubt, the rods should be used.

(2) When the adjusting tanks are full and both the ballast tank and the lower compartment *are full* at the same time, the chamber has a negative buoyancy of about 3,000 pounds and will sink. With the ballast tank and the lower compartment *empty* at the same time, and the adjusting tanks full, the chamber has a positive buoyancy of about 5,000 pounds and is too light, unless, of course, it is floating on the surface.

(3) A convenient telephone call system for directing the chamber crew to answer a call from the surface consists in turning the master lighting switch on the surface vessel off and on again. The blink of the lights in the chamber directs the crew to man the telephone, doing away with the necessity of one operator keeping the phone continually to his ears. The phone on the surface shall be manned at all times.

(4) The operators shall endeavor to maintain the pressure in the upper compartment atmospheric. The upper compartment vent should be kept closed while the motor is running in order that any pressure in the compartment will not increase the back pressure on the motor.

(5) The bilge in the upper compartment may be pumped with the hand suction pump provided with the chamber. The water is ejected into a bucket which is then dumped overboard or into the lower compartment.

(6) Whenever a pressure is built up in the upper compartment, it is well to take one plug from the top of each adjusting tank and leave it off until the pressure is reduced. Otherwise the pressure will drive the plugs tightly into the holes, and may force them through the holes entirely if the cans are empty.

(7) The guard ring for the rubber gasket on the bottom of the chamber should always be attached except when the chamber is in the water.

94–157. RESCUE CHAMBER TRAINING

(1) To assure skill in the use of the rescue chamber, exercises shall be held in accordance with Submarine Force instructions. The exercises shall simulate as closely as possible the rescue of the crew of a sunken submarine, and every step which would be necessary in an emergency shall be carried out.

(2) It is desirable that there shall be an officer with the crew each trip. As many officers and enlisted men as practicable should make themselves thoroughly familiar with the operations of the chamber.

(3) By using a false hatchseat, rescue chamber training may be carried out at the dock without the use of a submarine. This seat is made of ¾- to 1-inch steel plate anchored by welding to a sufficient number of channel bars to bring the total weight up to 2,000 pounds. It is placed on the sea bottom with the plate uppermost and as nearly horizontal as possible. A pad eye in the center of the plate simulates the submarine hatch spindle, and four other pad eyes are placed on the plate for attaching the holding down rods. Operation with this seat is exactly the same as with a submarine, making and breaking the seal, clamping on the rods, etc.

94–158. CARE OF RESCUE CHAMBER

(1) The rescue chamber requires very little attention when not in use, but a monthly inspection of it shall be made to insure that it is in proper working condition, and that all parts of it are protected from corrosion and deterioration.

(2) To lay up rescue chambers after use:

(*a*) Grease all Zirk fittings on reel, shaft, and hatches.

(*b*) Disconnect air supply line to motor and pour a little light oil into motor through the line.

(*c*) Examine gaskets and knife edges. Clean the latter and cover with light oil.

(*d*) Run out the downhaul cable from the reel.

(*e*) Rewind the cable, slushing with heavy grease.

(*f*) Cover the dogs and exposed portions of the hatches with light oil.

(*g*) Chip and paint any rusted spots on the hull, inside or out.

(*h*) Examine and clean the fittings on the top of the chamber.

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